The

ENGINEERS' DIGEST

REVIEW OF ENGINEERING PROGRESS ABROAD

VOL. IV. No. 3

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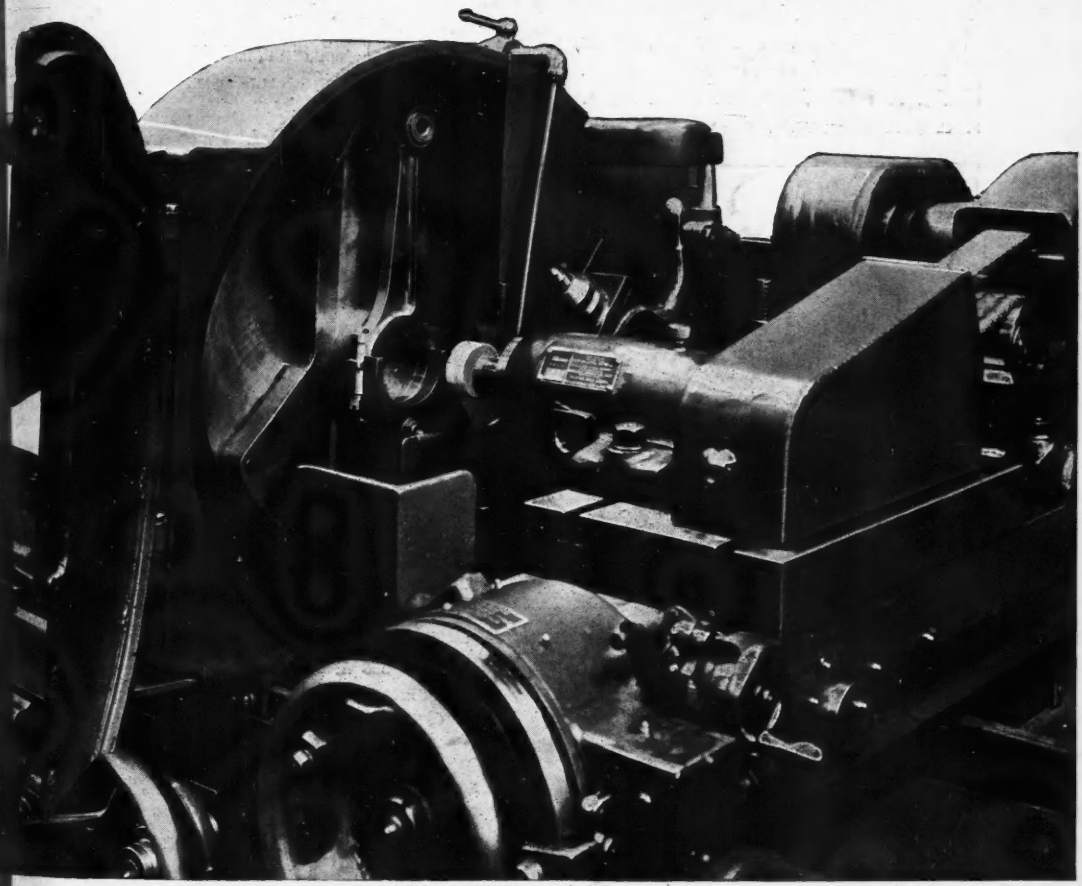

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REVIEW OF ENGINEERING PROGRESS ABROAD

Published Monthly at 120, Wigmore Street, London, W. 1.

Publishers : **ENGINEERS' DIGEST LTD.** - - - - Telephone : WELBECK 9357

Advertisement Dept. - 120, Wigmore Street, London, W.1 - Telephone : Welbeck 9357

Distribution - - E. & F. N. SPON, LTD., 57, Haymarket, London, S.W.1
Telephone : Whitehall 1860. Telegrams : Fenspon, Lesquare, London

Editorial Dept. - - 120, Wigmore Street, London, W.1 - Telephone : Welbeck 9357

Subscriptions to : ENGINEERS' DIGEST LTD., 120, Wigmore Street, London, W.1, or
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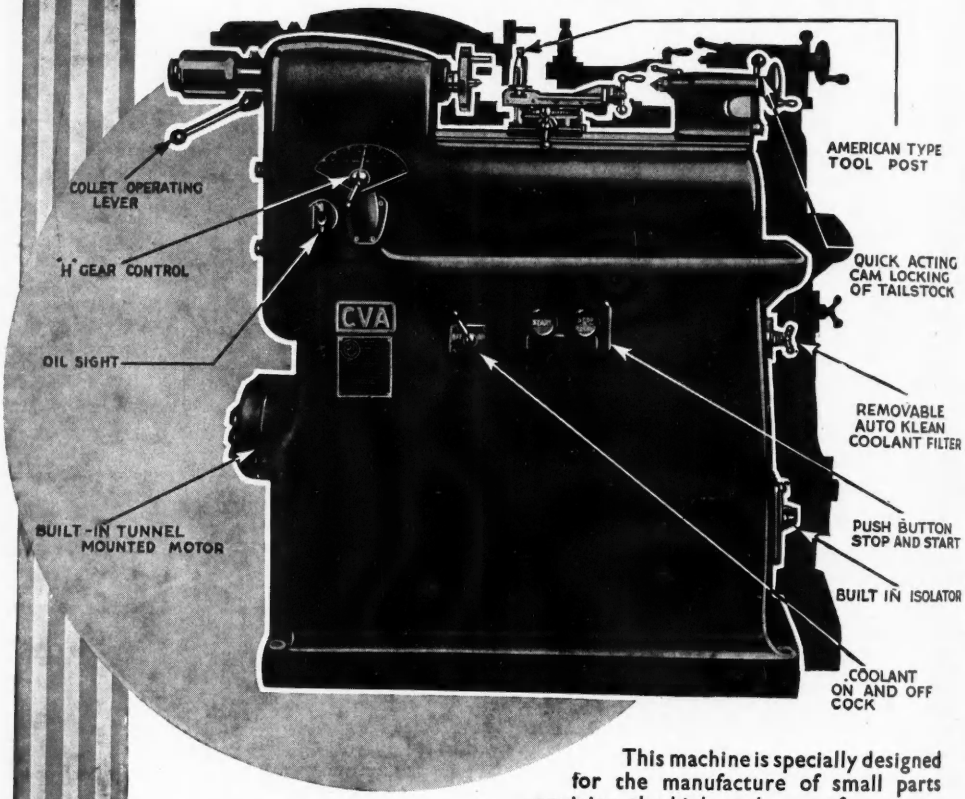

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GAS TEMPERATURE MEASUREMENTS IN INTERNAL COMBUSTION ENGINES

By Dr. Ing. H. Graff. (From *VDI-Zeitschrift*, Vol. 86, No. 29-30, July 25th, 1942, pp. 461-466).

As a rule thermocouples, and occasionally electric resistance thermometers are used for temperature measurement of exhaust gases of internal combustion engines. The main source of error in these methods is heat conduction and radiation to the ambient air. Additional heating of the thermocouple to compensate the error is omitted owing to the increased difficulty of measurements. The error produced by the heat conduction through the protecting tube of the thermocouple can be considerably reduced by chosing a material of small conductivity and by making the cross-section of the tube as small as possible. It is quite useless to reduce radiation losses by using a protecting tube made of a material of low emissivity as, after a short time, a black deposit of high emissivity is formed ; furthermore, the emissivity of such materials becomes very large at high temperatures. With thermocouples the radiation losses alone can give errors up to 100° C.

The error depends also on the mixture strength; with rich mixture the error is about 30% less than with a lean mixture, as with the former the exhaust gases contain soot particles which reduce the heat transfer between the thermocouple and the cooler exhaust pipe. That is why exhaust thermocouples should be used with care even if only comparative results are desired. Thermocouples cannot be used for temperature measurements in the combustion chamber owing to the large inertia of the instruments. The indicated "mean temperature" is deceptive as there is no linear relation between heat radiation and gas temperature, the heat-transfer depending on many undeterminable factors.

Temperature Measurements without Inertia Effects.

As it is impossible to measure directly gas temperatures in Otto or Diesel engines, one has to measure certain properties of the gases, which depend on their temperature, and follow the temperature variations without any inertia. Such properties are always of molecular nature as, e.g., ionization and radiation. By means of thermal or chemical excitation a certain potential energy is given to the molecules, which is completely or partly lost again by radiation. The stronger the excitation the shorter will be the wave length of the radiation. Ionization is an especially strong form of excitation, the molecules being split up into electrically charged particles.

The measuring instruments which must be sensitive to the above mentioned properties of the combustion gases can be made with or without inertia, according to the purpose of the measurements. For measurements without inertia, ionization paths and photo-cells are used to measure ionization and radiation respectively. Both instruments are used in conjunction with an amplifier. Instruments with inertia are used in connection with a stroboscope which exposes the measuring instrument to the radiation of the engine cylinder once each cycle. By means of shifting the time of exposure to any part of the cycle, the temperature course of the whole combustion cycle can be determined point by point. By using light-sensitive film the complete radiation curve can be obtained with a single measurement. The film is fixed to a drum rotating at synchronous speed with the engine. In the direction of the axis either spectral distribution of the radiation energy, or intensity distribution along the combustion chamber can be registered on the film.

As for a sufficient exposure of the film many cycles are required, the measurement represents a mean value of the radiation, and thus of the temperature during that period.

Ionization Method.

When the flame front reaches a part of the combustion chamber, it becomes electrically conducting : the neutral gas molecules are ionized by thermal excitation, and the motion of these ions forms the current passing between two electrodes at different potentials. The current is amplified and recorded by an oscillograph. The ionization gap is made up in a manner similar to sparking plugs, the electrodes of which may be lengthened. Electrodes projecting into the combustion space must be of heat resisting, stainless material, and completely insulated, otherwise an exact local determination of the flame front propagation is impossible (Fig. 1).

This method is a very simple one. Difficulties, however, are encountered in transforming ionization currents to temperature readings by means of the Saha-Boltzmann equation as the composition of the hot gas, with its numerous unstable components, is unknown. Hence the calculation of the temperatures is omitted, and the method is used for the determination of the rate of flame propagation only.

This method has proved successful both for Diesel and Otto cycle engines. With the use of sufficiently small ionization gaps it is possible to follow flame travel very accurately. If many of these ionization gaps are used, the rate of flame propagation can be measured with an accuracy of 10^{-4} secs.

Radiometric Method.

The radiation measurements, too, make use of the properties of the molecules in the combustion space, but as this involves only small excitation energies, such measurements are rarely performed in the ultraviolet part of the spectrum ; usually visible light or the neighbouring infra-red light is used. The range of wave length of light that can be used for the measurements is determined by the properties of the quartz windows ; 200 to 3000 mμ passes through almost without loss.

It is necessary to distinguish between the radiation of Diesel and Otto cycle engines. In Diesel engines the radiation consists mainly of that from solid soot particles. A spectrum containing all colours uniformly distributed is therefore obtained. It is similar to that of a black or grey body ; only separate lines and bands stand out. The radiation of the Otto cycle engine is mainly a band radiation emitted by certain groups of atoms, as, e.g., C-H, C-C, O-H, C-N radicals, and also carbon dioxide and steam. In contrast to the black

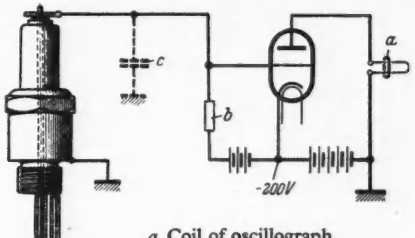


Fig. 1

a Coil of oscillograph,
b Grid leak of ionization path,
c Earth capacity of lead.

Usual circuit diagram of an ionization path with an earthed electrode.

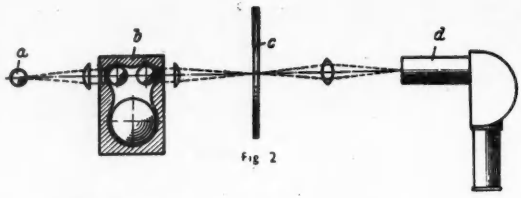


Fig 2

Path of rays in the spectral line reversal method.
a Bulb; *b* Cylinder head with two quartz windows; *c* Stroboscopic disc; *d* Spectroscope.

radiation of the Diesel engine, the intensity of these separate bands does not depend on the temperature only, but also on the total pressure and the distribution of the various gas components. Besides this band radiation there is also a continuous radiation which, however, is very slight in case of weak mixtures. It results, probably, from unburnt fuel particles or hot oil drops that get past the piston into the combustion chamber. Over-rich mixture increases this continuous radiation. The measuring methods have to take these facts into consideration.

Stroboscopic Radiometric Method.

Hershey measured the emission and absorption of the flame gases through two quartz windows in the wall of the cylinder on opposite sides of the combustion chamber. A thermopile was used as receiver. Owing to the inertia of this instrument a stroboscopic disc had to be used. The absorption measurements were inaccurate because of the small absorptivities obtained. The temperatures were calculated according to H. Schmidt's law derived from the laws of Kirchoff and of Stephan and Boltzmann. The assumptions in the measurements, as Hershey emphasised himself, are uncertain as the radiation law is based on the total radiation, and not on the part of the spectrum only which passes through the quartz window. The discontinuous character of the radiation of the Otto cycle engine is a great handicap in all measurements with an instrument that is not particularly sensitive to a certain colour. It seems that a spectral resolution of the radiation would reduce the uncertainty of such measurements.

Temperature measurements based on spectroscopic principles have been tried on Diesel engines. Erichsen resolved the radiation of Diesel engines by means of a spectrograph and recorded the spectrum on a film fixed to a drum rotating at synchronous speed with the crankshaft. In Diesel engines the temperature radiation has a distinct short wave length limit, this limit being shifted towards shorter wave lengths with increasing temperature. The wave length at which the blackening of the film begins at a certain crankshaft position is a measure of the temperature at this instant. Here Erichsen made the simplifying assumption that the energy of the light corresponding to a certain degree of film blackening is the same for all wave lengths. Such a measurement cannot be considered fully reliable as the ultraviolet spectrograph gives great dispersion at shorter wave lengths; furthermore, film blackening can be determined photometrically with little accuracy, and, according to Erichsen, there is a luminescent band radiation in Diesel engines which must result in erroneous temperature indications as soon as the blackening commences in this spectrum range.

Schroeder used a glass filter or a spectrograph to filter off the red radiation and measured the blackening of the film fixed to a rotating drum with a photometer. By suitably arranging several stroboscopic discs he was able to record on the film emission, absorption, and also the radiation of a light source for comparison. He found that the absorption coefficient of the flame was almost unity with the considerably thick layer (170 mm.) of gas penetrated, i.e., the flame radiated black. Hence he could use the blackening of the film by the flame as a measure of the true temperature of the combustion gases.

The spectral line reversal method is usually used in Otto cycle engines. Again two quartz windows are fixed in the cylinder wall. A sodium salt (carbonate, chloride, alcoholate or ethylate) is added to the fuel mixture, resulting in the light yellow sodium-D-line in the spectrum of the combustion gases. If the light of an electric bulb, placed on the side of the engine opposite the spectroscope, is passed through the combustion chamber and a certain period of time is selected by means of a stroboscopic disc (Fig. 2), in addition to the sodium line, the continuous spectrum of the bulb can be seen. According to whether the temperature of the bulb is lower or higher than that of the burning gases, a dark line on a light background, or a light line on a darker background will be obtained. The temperatures of the bulb and the gases will be the same if the sodium line is as light as the adjacent continuous spectrum, i.e., if the sodium line disappears.

The spectral line reversal method gives correct temperatures under the following conditions:

1. The combustion gas temperature must not be altered by the introduction of the sodium salt.
2. The sodium atoms must be in thermal equilibrium with the gas, and their radiation properties must satisfy Kirchhoff's law.
3. The gas temperature must be constant between the two quartz windows.

The first requirement can be easily fulfilled as the introduced quantity of sodium is very small, viz., only about 5.10^{-6} by weight of the fuel used. The second requirement has been frequently discussed. Whilst Erichsen claims to have found luminous radiation, i.e., radiation by chemical excitation of the sodium line, other authors' measurements are in favour of the spectral line reversal method. The third requirement according to measurements by Rassweiler and Withrow, is generally not fulfilled. The temperature differences in the combustion space, in this case, were up to 300°. Though there are temperature variations along the measuring length, the obtained temperature lies definitely between the highest and lowest temperature. It seems reasonable to assume, therefore, that the temperature obtained by the spectral line reversal method corresponds very nearly to the mean temperature of the measuring length.

Continuous Radiation Measurements.

The methods discussed above are not suitable for continuous temperature measurements in test engines. Attempts have been made, therefore, to use only one

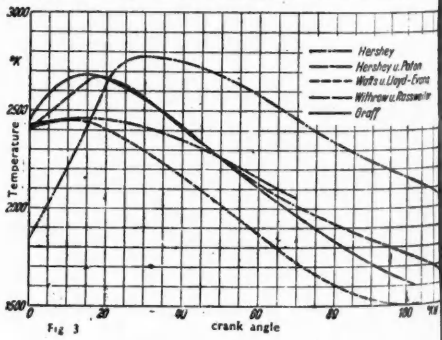


Fig 3

Results of various stroboscopic temperature measurements on the Otto cycle engine.

quartz window and a photo-cell in order to measure the radiation of the combustion gases. The photo-cell, especially the vacuum-cell, has practically no inertia. Cathode-Ray or Electro-Magnetic oscillographs are used to record the photo-current, in which case sufficient amplification has to be provided. If minimum inertia is required, a cathode-ray oscillograph has to be used, otherwise an Electro-Magnetic oscillograph will suffice. The amount of inertia can be expressed by what is called "Limiting Frequency," i.e., the highest frequency which is just possible either to amplify or record. The Limiting Frequency of electro-magnetic oscillographs with coils that can be still actuated by low voltage elements, is approximately 2000 cycles per second. In the construction of the amplifier, a suitable ratio of minimum inertia and maximum sensitivity must be found, both depending inversely on the size of the photo-electric resistance. When the electro-magnetic oscillograph is used, the limiting frequency of the amplifier should not be raised above that of the coil and conversely, the low inertia of the Cathode-Ray oscillograph should not be spoiled by an amplifier of low limiting frequency. The limiting frequency of the amplifier is dependent on the size of the photo-cell resistance R and the earth capacity C and is expressed by the equation $\nu_{Gr} = \frac{1}{2\pi RC}$.

When a cable of 5 m. length is used, the capacity between the cell and the amplifier is about 150 pF (1 pF = $\mu\mu$F); therefore, with the electro-magnetic oscillograph, the resistance must be decreased at the cost of the sensitivity, according to the minimum inertia required. These considerations are also valid when an ionization gap is used. An obvious step was to measure the self-radiation of the combustion gases by means of a photo-cell and hence to deduce the temperature. The differences between the measurements are due to the different sensitivity of the photo-cell to different parts of the spectrum and to the different characteristics of the substances which are radiating. Lieb measured the radiation on a low speed Diesel engine in the blue part of the spectrum (λ max = 440 mμ), while Bisang measured the radiation on Otto cycle and Diesel engines in the infra-red part of the spectrum (λ max = 970 mμ). Bisang wanted to calibrate the photo-cell by means of a carbon furnace, into which the exhaust was led. This calibration, however, was only possible up to 1850° K.

The radiation, most probably, does not depend only on the temperature of the gases, but also on the pressure and gas composition; hence it is impossible, even at constant operating conditions, to attribute a definite temperature to a definite radiation. Thus Bisang's calibration of the photo-cell at atmospheric pressure will lead to false temperatures.

As the radiation properties of the intermediate and final combustion products are not sufficiently well defined and partly unknown, exact temperature measurements, by means of the radiation of certain additives which have the required radiation properties were attempted. The alkaline metals proved to be suitable. Yosida added to the fuel sodium ethylate, and measured the radiation of the yellow Na-D-line during the combustion by means of a photo-cell. He further measured the highest temperatures obtained with different fuel mixtures by means of the line reversal method and compared the radiation with the corresponding temperatures; an exponential relation corresponding to Wien's law of radiation was obtained. Yosida concluded from this that the radiation of the Na-D-lines can be used for temperature measurements in an engine.

Materials, therefore, which are used as additives in the line reversal method seem to emit, within the range of their "Resonance line," a total radiation independent of any other factors but temperature. The

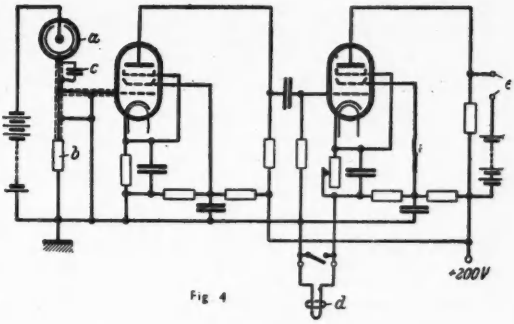


Fig. 4

Circuit diagram of a Photo-cell Amplifier.
a Photo-cell; *b* Grid-leak; *c* Earth capacity of photo-cell and lead; *d* Coil of oscillograph; *e* Terminals for cathode-ray oscillograph.

"resonance line" is the spectral line which is emitted by the atom when falling back from the lowest state of excitation into the basic state. This was investigated by Graff on potassium lines (λ = 766.5/769.9 m μ). On comparing the temperature measurements obtained by the spectral line reversal method and the radiation method using a specially sensitive photo-cell the following conclusions were arrived at.

1. The radiation of the potassium lines is practically independent of pressure in the combustion chamber, except with very small quantities of potassium of less than 0.02 grams in 1 litre of fuel.

2. The radiation depends on temperature as stated by Planck's law of black-body radiation, if the wave length of potassium is substituted for wave length in the formula.

3. The radiation depends on the ratio of potassium to fuel. This relationship was determined experimentally.

4. Using colour filters in front of the photo-cell the continuous and band radiation was absorbed to such an extent that it had no noticeable influence on the radiation measurement.

With these results a new method of temperature measurements was developed, using only one quartz window in the combustion chamber, a photo-cell and colour filters. The error of the measurements was ±1.5%. The lowest temperature that can be measured without having to use any special apparatus is about 1000° K; the apparatus does not limit the highest temperature that can be measured. The transformation of radiation to temperatures is laborious, as a great number of variables have to be considered: the amount of potassium added, the light-sensitivity of the arrangement of quartz window and photo-cell, the anode voltage of the photo-cell, and the amplification of the photo-cell current.

This arrangement is satisfactory, giving continuous measurements without inertia effects, not too large a requirement in the way of instruments, comparatively easy interpretations of the readings obtained and a high degree of reliability of the measurements. The method fails only in one case, i.e., when the radiation of the solid soot particles which are contained in the gas becomes noticeable compared with the radiation of the potassium. In this case, which does not occur even with over-rich fuel mixtures with the usual Otto cycle engine, absolute temperature measurements fail. This state of affairs appears to be only possible under knocking conditions. When the method is used under knocking conditions temperatures of more than 3000° K are obtained that do not agree with the measurements of Rassweiler and Withrow.

SPOT WELDING OF ALUMINIUM AND ALUMINIUM ALLOY SHEET METAL WITH A 60 kVA MACHINE

By Dr. R. Irmann. (From *Schweizerische Bauzeitung*, Vol. 120, No. 16, October 17th, 1942, pp. 179-183).

Spot welding of aluminium differs from that of iron because of the higher electric conductivity and lower melting point of aluminium. Aluminium also has a temperature range below its melting point in which the material is in a plastic state.

The high electric conductivity of aluminium necessitates a large welding current. The variations of conductivity with different aluminium alloys must be allowed for by adjusting the current and the welding time accordingly. The electric conductivity and melting point of some aluminium alloys are given in Table 1.

Table I.

Alloy	Melting Interval		Electric Conductivity at 20° $\frac{m}{\Omega mm^2}$
	from °C.	to °C.	
Pure Aluminium	—	658	34 —36
Aluman	640	650	22 —28
Peraluman 1	620	635	20 —26
Peraluman 3	580	640	20 —23
Peraluman 5	570	635	15 —18
Peraluman 7	540	610	13 —16
Anticorodal	590	645	24x —32xx
Avional	530	650	19x —30xx
x tempered			
xx soft			

The oxide film present on any aluminium surface is an important criterion in spot welding, as it increases the resistance between electrode and aluminium, thus causing surface burning. As the strength of the aluminium at the weld is considerably decreased by overheating, and as the electrode pressure influences the heat developed, this has to be adjusted accordingly.

The following tests have been performed with a spot welding machine type GPS-60-kVA (Schlatter, Zollikon), the transformer of which has a maximum output of about 150 kVA. The circuit diagram of the machine is shown in Fig. 1.

The welding transformer (A) can be adjusted in 36 steps by means of the two switches (E) which provide a coarse and a fine adjustment respectively. The transformer consists of a primary winding (P) and a secondary winding (S), the ends of which are connected to the upper electrode holder (H_o) and lower electrode holder (H_u) respectively. The material to be welded is placed between the two holders H-H which are provided with copper electrodes; by pressing down the pedal (J) the rods with the weights L-L are lifted by the lever (K) thus the pressure, regulated by the spring (O) and the wheel (N) is exerted on the pieces to be welded. The spring pressure has been successfully replaced recently by pneumatic pressure. The adjustable link (M) actuates the switch (G) which through a control switch causes the contact (C) to close. At the same time a transformer supplies the voltage to a gas-filled rectifier valve which, through adjustable resistances (coarse and fine adjustment D) charges a condenser. When the latter reaches the critical voltage of the built-in thyratron it discharges through this valve which is in series with a d.-c. relay. The relay interrupts the coil circuit of the main switch which then breaks the main circuit and thus stops the welding. According to the series resistance used welding times ranging from 0.03 to 3 sec. can be attained. In order to charge the condenser after each spot weld from zero voltage a small relay is built into the timing instrument which shuts the condenser for a short time after each functioning. The following points will have to be considered:

(1) The surface of the material to be welded.

(2) The quality of the electrodes and electrode pressure.

(3) The welding current and welding time.

The weld can be tested (a) by determining its mechanical properties, (b) by determining the structure of the spot weld.

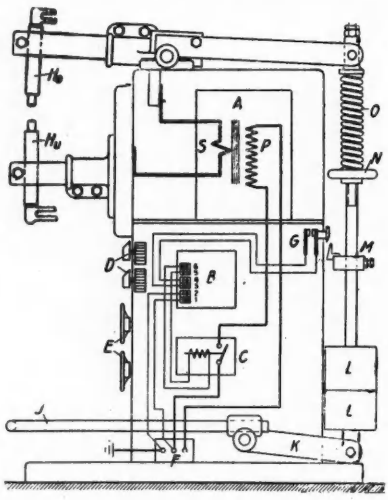


Fig. 1

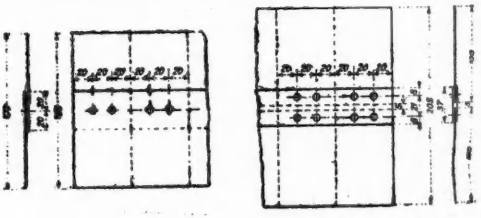


Fig. 2 Test specimens. A (left), B (right).

Single and double lapped specimens are shown in Fig. 2. The distance between the spots is 20 mm. The strength of the joint is expressed in kg per spot weld, and should not be calculated from the cross-section of the spot weld, as the latter cannot be determined accurately. The strength of double lapped joints is similarly determined, and is about twice that of a single lapped joint. Fracture can occur in two ways; either the sheet tears round the spot weld, which happens mostly with sheets of less than 1 mm. thickness and with soft materials; or shearing occurs at the spot weld between the two sheets.

Bending reduces the strength of a lap joint considerably. Fig. 3 shows the arrangement used to test spot welds in tension. As the strength of the weld is considerably less in tension than in shear, spot welded joints, similarly to riveted joints, should be used, if possible in shear only. A good method of examination

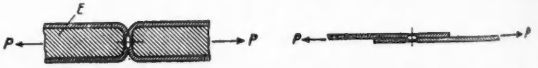


Fig. 3 Spot weld in tension (left), in shear (right).

is to make a section through the weld; the size and position of the welding zone can then be determined and pores and tears in the spot weld can be detected.

Surface of the material.

The oxide film covering the surface of aluminium has a high electric resistance. Though this film can be partly broken by the electrode pressure, the high resistance results in overheating of the aluminium and forms a copper alloy where contact takes place with the copper electrodes. Thus the surface of both the aluminium and the copper electrode is spoiled, and it becomes impossible to obtain a clean weld. It is not possible to use electrodes other than made of copper as high electric conductivity is needed.

The best way of removing the oxide film is by means of a steel brush of about 0.2 mm. diameter wire. Emery paper can be also used. It has been also recommended to insert a copper strip between the copper or tombak electrode and the aluminium surface. This is automatically fed during welding, so that at each spot weld a new piece of the strip is used.

The oxide film should be removed from the surface of the aluminium only where the electrodes make contact, since a high resistance is desirable between the two aluminium parts to be joined. In the case of thin sheets of less than 0.5 mm. thickness a high resistance due to an excessive oxide film can lead to squirting away of aluminium in the form of small metal beads. In this case it is impossible to achieve a clean weld and it is necessary, therefore, to brush the parts at the weld, too. Brushing at the contact of the two sheets is not necessary with pure aluminium and aluman, which are covered only with a very thin oxide film; it is necessary, however, with all alloys such as Peraluman, Anticorodal and Avional. With Anticorodal and Avional of 1 mm. thickness it is advisable to brush the inside of the sheet metals, as during tempering a relatively thick oxide and nitride film is formed.

The Electrodes.

Because of the high electric conductivity required electrodes are mostly made of electrolytic copper, and in few cases only of copper alloys. Hard drawn copper is very successful as it deforms less under the electrode pressure. To prevent overheating and the formation of alloys with the aluminium, water cooled electrodes are used. Recently electrodes cooled by means of a freezing mixture have been suggested.

Electrodes are often made rounded, but it is easier to make them conical or flat. The conical electrode penetrates deeper into the metal although its electrical welding resistance is smaller. The angle of the cone is usually 7° to 11°. If cleaning with emery paper is necessary the shape of the cone is spoiled; for sheet metals up to 1.5 mm. thickness flat electrodes of 5 mm. diameter, and for sheet metals of greater thickness flat

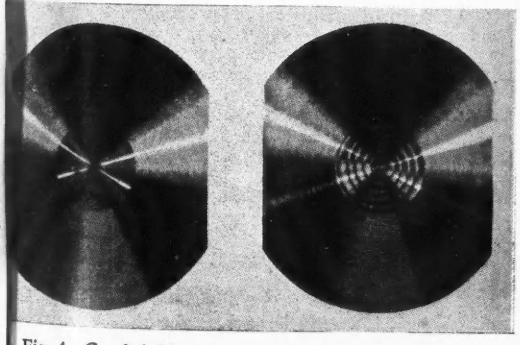


Fig. 4 Good (left) and bad (right) electrode surface.

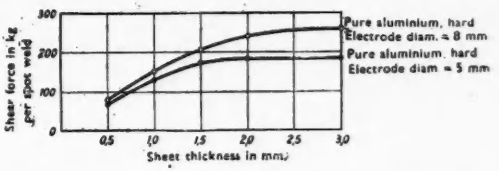


Fig. 5

electrodes of 8 mm. diameter are used. Flat electrodes are easy to manufacture, but a good finishing is important for a proper contact between electrode and aluminium. The electrode is less likely to stick to the aluminium in this case as if they are conical since the current density is more uniform. Sticking of the electrodes can be prevented by covering the aluminium with a thin film of oil or fat which evaporates during welding.

The influence of electrode diameter on the shear strength of a weld of pure hard aluminium sheet metal of up to 3 mm. thickness is shown in Fig. 5. Generally, the electrode diameter should be increased with increasing sheet metal thickness to keep the specific current density constant. This, however, is only possible with very powerful machines.

Electrode Pressure.

The electrode pressure is mostly obtained through a compressed air cylinder. With 5 mm. diameter electrodes pressures ranging from 200 to 300 kg are used for sheet metals of 0.5 to 1.5 mm. thickness. With 8 mm. diameter electrodes a 300 kg pressure has to be provided.

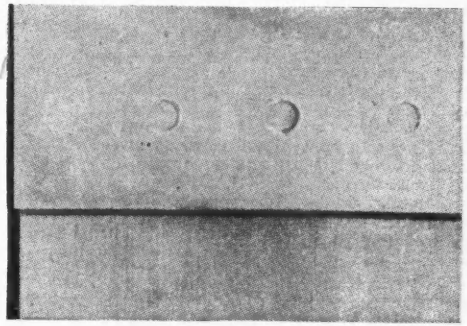


Fig. 6 Left: Slight scorching, electrode pressure = 100 kg, right: clean spots, electrode pressure = 200 kg.

The pressure should be adjusted according to the sheet metal thickness and also according to the material to be welded, pure aluminium being softer than aluminium alloys. The machine, however, is simpler in operation when the pressure is adjusted according to the electrode thickness only, and if a mean pressure is used for any sheet metal thickness and for different materials.

Too large an electrode pressure results in a too deep indentation; on the other hand too low a pressure results in burning of the electrodes, because of the high electric resistance between sheet metal and electrode. This fact is demonstrated in Fig. 6.

Current Strength and Welding Time.

All possible current strengths and welding times have been tried out on single lapped joints made of pure aluminium, Aluman, Peraluman 1, 3, 5, 7 as well as Anticordal and Avional soft and tempered. The optimum current strength and welding time were determined from the appearance and quality of the weld. The results of these experiments are shown in Table II. The longer the welding time the greater the

TABLE II.

Alloy	Sheet Thickness mm.	Surface	Electrode Pressure kg.	Electrode Pressure atm.	Electrode dia. mm.	Transformer coarse	Transformer fine	Time Adjustment
Pure Al. W-H Aluman	0.5	O	200	2.7	5	5	1	1- 2
	1.0	O	200	2.7	5	5	6	1- 2
	1.5	O	200	2.7	5	6	1	1- 2
	2.0	O	300	4.0	8	6	6	8-12
	3.0	O	300	4.0	8	6	6	10-15
Peraluman 1, 3, 5 & 7 W-H	0.5	X	200	2.7	5	4	6	1
	1.0	O	200	2.7	5	5	1	1- 2
	1.5	O	200	2.7	5	5	3	1- 2
	2.0	O	300	4.0	8	6	6	2- 4
	3.0	O	300	4.0	8	6	6	3- 6
Anticorodal W/A/B	0.5	X	200	2.7	5	5	1	1
	1.0	□	200	2.7	5	5	6	1- 2
	1.0	O	200	2.7	5	5	1	1- 2
	1.5	O	200	2.7	5	5	6	1- 2
	2.0	O	300	4.0	4	8	6	4- 7
	3.0	O	300	4.0	8	6	6	6-10
Avional W/D/M SK	0.5	X	200	2.7	5	4	6	1
	1.0	□	200	2.7	5	5	6	1- 2
	1.0	O	200	2.7	5	4	6	1- 2
	1.5	O	200	2.7	5	5	1	1- 2
	2.0	O	300	4.0	8	6	6	2- 5
	3.0	O	300	4.0	8	6	6	4- 8

O—Brushed outside. X—Brushed on both sides. □—Brushed on both sides; material hardened.

wear of the electrodes and the more difficult it is to make a good weld. It is obvious that the welding times given in Table II. can be varied within certain limits. Likewise the electrode diameter and pressure can be varied, as the welding conditions depend also on the sheet metal surface.

It should be pointed out, that the above tests were carried out with electrode rods of about 350 mm. length. The larger the discharges the larger the current losses, and consequently with smaller discharges better welding conditions and higher efficiencies can be obtained.

Fig. 8 shows graphs obtained by plotting shear force in kg per spot weld against distance between spot welds in mm. The strength of a spot weld with sheet metals of 1 mm. thickness varies from 130 to 230 kg according to the alloy used. Additional bending or tension reduces the strength of the weld considerably. The fatigue strength is lower than that of a riveted joint.

It should be noted that the strength obtainable depends on the distance between the spot welds. The whole current cannot be utilised in welding as a part of it passes through the neighbouring spot weld and is therefore lost in the shunt. The nearer the spot welds the larger the current loss; this naturally influences the strength of the welds. A graph of shear force in kg per spot weld plotted against distance between spot welds in mm. demonstrates this fact.

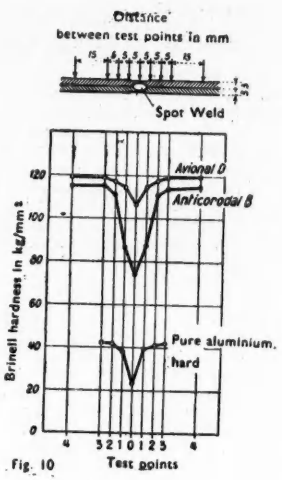


Fig. 10

Fig. 9 illustrates the strength of welds carried out with rectangular electrodes using a distance of 20 mm. between the spot welds (1) without distance between spot welds, (2) and with overlapping spot welds. Anticorodal (B) of 1 mm. thickness was used. The strength from spot 1 to 3 decreases to about one half per spot weld (curve A) while, naturally, the strength of the total weld increases at welds 2 and 3 (curve B). This type of weld is similar to a seam weld.

In autogeneous and electrical welding there is on

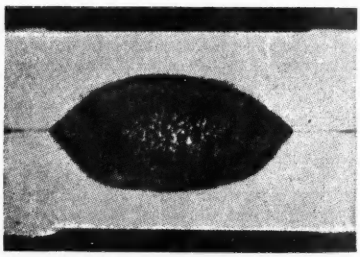


Fig. 11 Normal, correct spot weld.

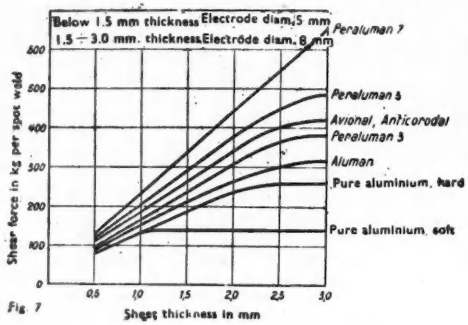


Fig. 7

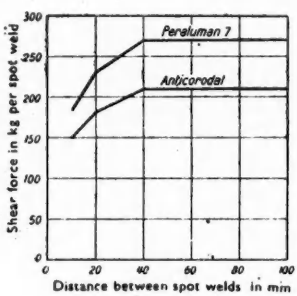


Fig. 8

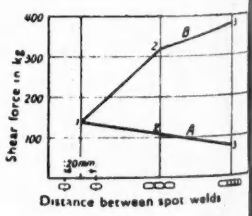


Fig. 9

Influence of distance between spot welds

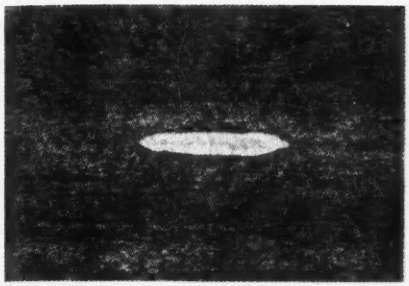


Fig. 12 Too small spot weld.

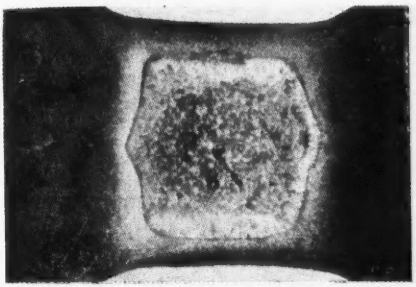


Fig. 13 Too large spot weld with pores and tears.

both sides of the weld a softening of the material for several centimeters. In spot welding of hard rolled or tempered alloys, such as Anticorodal or Avional, the material is softened for 5 mm. on both sides of the weld. The dimensions of the softening zone with different materials are demonstrated in Fig. 10. A re-tempering of spot welded Avional and Anticorodal, as it is done in autogeneous and electrical welding, is not necessary.

THE TECHNIQUE OF MELTING AND THE CASTING PROPERTIES OF ALUMINIUM AND ALUMINIUM ALLOYS

(Communication of Metallurgical Laboratory of the United Aluminium Works, Ltd., Lautawerk, N.L.).

By HANS ROEHRIG. (From *Die Giesserei*, Vol. 29, No. 17, August, 1942, pp. 285-291).

Varieties of oxide inclusions and their properties. Elimination of gases. Concentration of gases at the grain boundaries. A new method of hydrogenising aluminium melts. A method of etching to demonstrate gas cavities. Calculation of gas content to mechanical strength. Hints on melting procedure.

THE chief problem involved in the smelting and casting of high duty alloys is the treatment of the oxide and gas inclusions to which they are subject. This applies particularly to aluminium and aluminium-base alloys, since not only are they very susceptible to oxidation, but also their low specific gravity makes the elimination of gas a slow and difficult process.

The oxides are of two kinds :

1. Grain-like accretions of crystalline $\alpha\ Al_2O_3$ (corundum). These grains are of extreme hardness, and are, therefore, very injurious to tools.

Corund is formed by allowing the slag in the smelting bath to come into contact with air at very high temperatures. The aluminium diffused in the slag begins to glow, and some $\alpha\ Al_2O_3$ is formed. This reaction never occurs under 950°

The oxide grains, owing to their high specific gravity, tend to sink into the melt, from which they are very difficult to remove.

2. Oxide skins. These, although formed of a softer oxide, are tough and difficult to break up. Their tendency to form gas pockets and so hinder its release from the melt makes them a great nuisance, especially when the gas content of the melt is high.

Tendency to oxidation varies with the exact composition of the alloy ; the presence of the alkali metals or of zinc or magnesium tends to prevent oxidation. A melt containing sodium covers itself at once with a grey-blue skin, and, even after remaining at a high temperature for a considerable time, is found on solidification to be free from oxide.

Oxidation is expected by high temperatures and also by high water vapour content of the furnace gases. The effect of a large amount of moisture is apparent even at temperatures as low as 400-500°.

Formation of the skins is minimised by very slow cooling of the melt. On account of their low specific gravity the gas-filled globules rise to the surface as the metal cools.

Control of temperature and cooling time is not, however, always sufficient to prevent oxide formation, especially if the aluminium is not of high purity. In this case it may be necessary to " wash " the melt with a cleaning salt in order to dissolve the Al_2O_3 and so release the gas. The same effect may be produced by the addition of some electrolytic aluminium, the fluxing properties of which are sufficient to eliminate the oxide.

Analysis of the gas found in aluminium melts show that approximately 80% of it is hydrogen ; the rest consist of carbon dioxide, carbon monoxide and methane, with sometimes a trace of nitrogen.

The hydrogen is derived from the furnace gases (a) by direct absorption, and (B) from the water vapour which they contain in varying amounts. This moisture decomposes immediately on contact with the hot aluminium, and owing to its nascent state the hydrogen is greedily absorbed by the metal.

It is evident that the main factors favouring high gas content in a melt are large amounts of hydrogen, and hardly less important, of water vapour in the furnace gas. In this connection it is essential to ensure that the coke used should be in a dry condition.

It may be interesting to note that the presence of sodium in the melt increases absorption of hydrogen from the furnace gas. The sodium appears to act as a hydrogen carrier, but investigation of the subject is not yet complete.

The melt can be freed from gas in the following way. The temperature is reduced almost to melting point and the metal then allowed to cool very gradually in a closed oven. As the temperature drops the solubility of hydrogen in aluminium decreases, most of the gas being eliminated at the moment of solidification. A more effective method is to use an oven through which is directed a stream of fuel gas. This prevents the establishment of an equilibrium between the hydrogen over the melt and that in solution.

The greatest concentration of gas is found surrounding any corundum crystals which may have penetrated the melt. This can be demonstrated by an experiment with 99.99% aluminium (chosen to eliminate any disturbing influences). A graphite crucible is used, and the melting should be done in a resistance furnace. To introduce hydrogen a small amount of ammonium boro fluoride is used. The appropriate quantity is weighed wrapped in aluminium foil and dropped into

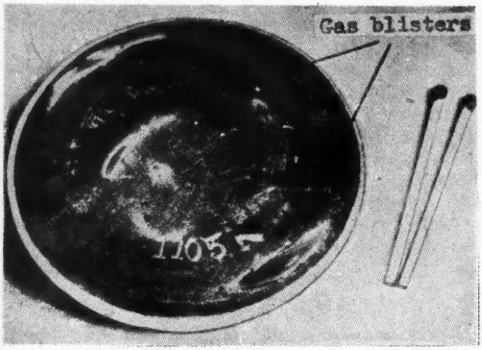


Fig. 1

the melt, in contact with which it immediately decomposes, with evolution of hydrogen. As the melt is cooled blisters of gas appear, particularly as solidification point is reached. The gas blisters first appear at the edges of the projections caused by the corundum grains (Figs. 1 and 2), and close examination of sections shows a concentration of gas bubbles over the surfaces of these structures and along their dendrites.

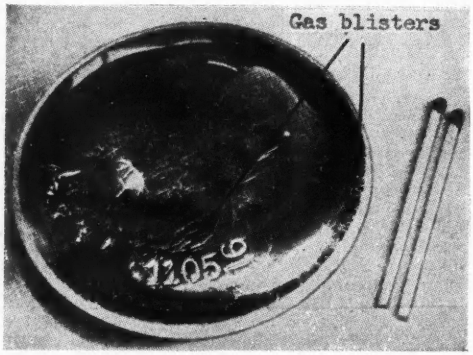


Fig. 2

The gas cavities are much more clearly seen in a sample of which the surface has been etched. Fig. 3 shows an untreated sample, and Fig. 4 the same section after etching. The etching is done with cold 5% sodium hydroxide. High purity aluminium should be treated

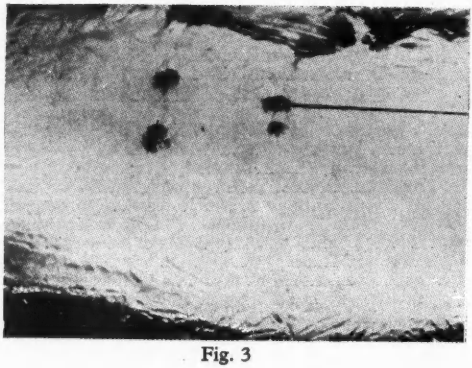


Fig. 3

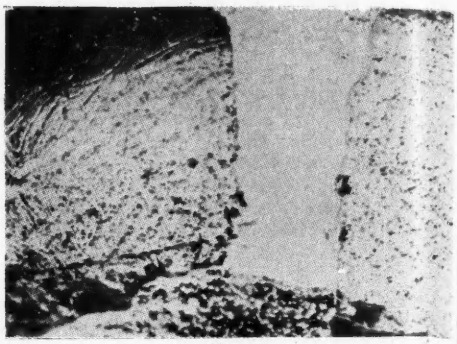


Fig. 4

for two hours. Aluminium of ordinary purity needs only 1 hour. In alloys the cavities appear in a few minutes.

Fig. 5 depicts a series of 6 etched samples to show that the evolution of hydrogen is directly proportional to the amount of ammonium boro fluoride added. All are slowly solidified melts of high purity aluminium. To produce the lowest sample the metal was heated to a temperature not exceeding 740°, and allowed to solidify slowly in the oven. It was then remelted, heated to 720°, kept at that temperature for 2 hours and again allowed to cool gradually. A test with the Pfeiffer vacuum apparatus proved it to be gas free.

To the remaining 5 samples ammonium boro fluoride was added in the following amounts :
2nd 0.01% 3rd 0.05% 4th 0.1% 5th 0.5% 6th 1.0%
It should be noted that with greater hydrogenation both the number and the size of the gas pores increase.

There is no doubt that the presence of corundum-

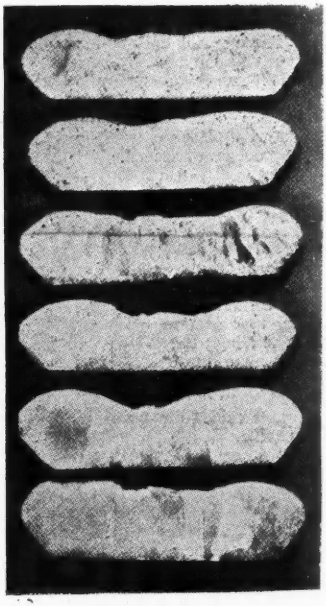


Fig. 5 Slowly cooled sample with increasing gas content (X 0.6).

grains with their accompanying aggregations of gas bubbles has a strongly adverse effect on the resistance of an alloy to corrosion, and also on its mechanical properties, especially tensile strength. The following table shows some figures for an aluminium-silicon alloy. The average on 14 bars was taken.

	Tensile strength kgm/sq. mm.	Elongation %
Gas free metal	+ 0.7 15.5 — 1.5	+ 0.5 4.4 — 0.4
Metal-containing gas	+ 2.5 15.0 — 1.8	+ 3.0 2.8 — 1.2

An aluminium-copper-magnesium alloy showed the following figures.

	Tensile strength kgm/sq. mm.	Elongation %
Gas free metal	20.0	3.5
Metal-containing gas	17.8	2.3

For routine purposes the gas content of alloys is usually calculated from the specific gravity as the Pfeiffer vacuum method is slow and somewhat difficult. The hot extraction method used in the laboratories at Lautawerk show for 99.5% Al a total gas content of 0.95 cc per 100 gm, of which 0.83 gm is hydrogen. After gasification with 6.01% ammonium boro fluoxide the total gas increases to 1.82 cc per 100 gm, of which 1.42 gm is hydrogen.

The results of all investigations demonstrate the deleterious effects of oxides and gas on the qualities of alloys, and the importance of the complete removal, or, better still, avoidance of these harmful elements. Any measure which lowers the moisture content of the furnace gas reduces the absorption of hydrogen into the melt, and also the danger of oxidation. If the furnace gas can be freed from hydrogen and water vapour high temperature has no ill effect. On the contrary, overheating in a weak oxidising atmosphere reduces the amount of sodium and other impurities which favour the absorption of hydrogen into the melt.

Finally it is suggested that for alloys on which very high demands are made, or when the available metal is very impure, the melting and cooling process should be done twice, using an oven of which the temperature can be regulated with extreme accuracy in order to ensure complete elimination of oxides and gas.

AIRCRAFT ENGINE BEARINGS

By THOMAS BARISH. (From *Machine Design*, Vol. 15, No. 1, January, 1943, pp. 72-73 and 138-144.)

FOR nearly every location on aircraft power plants, special ball and roller bearings have been developed. By far the most difficult problem arose with crankshaft bearings, which must take care of :

(1) Very heavy loads momentarily doubled due to gyroscopic forces which reach a peak in a tight spin.

(2) Large shaft deflections, the worst location being at the rear.

(3) High speeds. The present peak is about 6,000 ft./min.

(4) Relatively high temperatures.

Ball and roller bearings are employed on crankshafts only on the radial engine, primarily because of their compactness and ease of replacement. They also afford less dependence on a continuous oil supply and less susceptibility to deflections. Notch-filled type ball bearings are used except for a few of the smallest lightly loaded jobs. Sizes were first selected by arbitrary rules since the calculated loads far exceeded the ratings.

The gathering of experience followed the usual pattern for aviation work. A bearing selected for the rear end of a 550 h.p. engine nine years ago has not been changed although the engine has been improved step by step to over 1100 h.p. The first power increases eliminated the conrad type and specified only notch-filled type. That was found unsatisfactory above 850 h.p. with its extreme demands for reliability and long life. A square section roller bearing of the same dimensions was then introduced ; and finally, further power increases required improvements in these roller bearings. The following features have become standard for all heavily loaded locations :

(a) Edge relief of rollers. The high "Hertz" pressure along the centre of the rectangle tapers off sideways but changes abruptly at the end having no side support. Without edge relief failure occurs as a shear under this edge.

(b) Crowning of the outer race. The total yield in a straight 1-inch roller is only about 0.0002 inch, and a tilt of only 0.0002 inch or 1/10 degree would shift the contact entirely away from one end. Even more serious, the loaded end tends to drag and swerves the roller to one side. Crowning the outer race track largely eliminates these effects and without loss of capacity because the surface pressure of the concave outer can still be kept below that of the convex inner.

(c) A new one-piece retainer design with square broached holes permitting 10 to 20 per cent more rollers, primarily designed to eliminate the rivets which have always been a hazard.

(d) Control of the oil flow to the critical points in the bearing. These design features produced two to three times the life, and a marked reduction in operating temperatures, also in noise. Frequently all the inner rings of any one size are made interchangeable for replacement of separate parts. This involves extremely close production control and even then requires wider tolerances on internal looseness.

Much effort has been expended on the subject of internal looseness and fits. Shaft galling, due to high unit pressures with relatively narrow bearings, has been largely cured by increasing press fits to 0.0005-0.0007 inch minimum. Additional internal looseness is then needed as the maximum press fits often reach 0.0025 inch and inner races expand correspondingly.

High operating temperatures in bearings near the cylinders may produce slight softening of the steel and a small permanent growth in standard bearing steel. A new steel drawing technique corrected this condition by the use of much longer soaking. New alloys are also being tested. Several of the late U.S. engines follow English practice of eliminating inner races and having the rollers ride directly on the pinion extensions or gear shaft, thus eliminating fits, galling, and nuts for clamping.

Propeller Thrust and Radial Loads.

All but the smallest airplane engines employ the single-row radial ball bearing for the propeller thrust and radial loads. The major departures from standard

are in reduced "Aviation Widths." The notch-filled and conrad type ball bearings remain standard in all of the medium size group. Further increases in power brought forth a revival of an old Gurney bearing type with split inner race, comprising two angular contact type bearings in a single row. The bearing is designed to separate completely for thorough overhaul inspection.

The propeller bearing must carry a large momentary radial load due to gyroscopic forces when the airplane goes through violent gyrations. On all but the largest engines, the front ball bearing carries this large momentary radial load as well as the thrust load. The largest engines frequently introduce a separate roller bearing for radial support, but recent tests indicate that the new split inner race thrust bearing may make the roller unnecessary.

Rocker Arm Bearings Present Problems.

For large engine rocker arm bearings, a one-piece double-row ball bearing is used, with the maximum possible number and size of balls and no cage or separator. Tapered roller bearings of roughly similar design also are used. Very fine race finish and accurate balls are essential.

Besides high loads, the rocker arm location also involves high temperatures which soften the common ball and roller bearing steels. Fortunately these occur only during periods of maximum engine output. Noteworthy is the fact that inner races suffer more than outer races. High output engines have now been converted to oil lubrication for rocker arms, giving maintained lubrication, covering of surfaces to keep the air away and reducing the fretting corrosion action of "false brinelling," and better heat transfer to the cooling surfaces.

Precision Bearings meet Supercharger Requirements.

Extreme speeds and large power concentrations have been successfully met with the same super precision ball bearings originally developed for high speed frinder spindles. One very difficult problem is sealing against blower pressure alternating with high suction when throttled. In similar designs for cabin superchargers, the seals must be so tight as to prevent a leakage of even a smell of oil. The most common method provides two seals with a very liberal drain to the atmosphere between them to carry off any engine oil leakage and to permit only air leaking into the blower system.

The design of Fig. 1 was at first frequently used with two cylindrical roller bearings and one conrad ball bearing for thrust only, but in the U.S. was superseded by the three interchangeable radial type ball bearings shown. However, it is now questionable whether the change in bearing type contributed so much to the great increase in reliability as did the increased accuracy and certain radical changes in mounting principles as follows:

(a) Liberal oiling. The lubricant is not passed through the bearing but is permitted to wash off the sides, serving mainly for temperature equalization.

(b) Relatively loose bearings and looser fits in the housings.

(c) Present bearing capacity tables are practically ignored. Apparently the lower loads that go with extreme speeds are all within the fatigue limit. Based on present ratings, factors down to 0.35 (load/rating) are in use here and 0.20 on one foreign military engine.

Antifriction bearings prove highly desirable for the overhung rotors because the bearings are so close together, and small radial and axial clearances must be maintained between the blower and casing.

Controllable Propeller Blade Bearings.

The blades of a controllable propeller require rigid support and fairly free rotation for blade angle changes. The bearings must be designed for:

(1) Extremely large centrifugal forces (200,000 lbs. maximum).

(2) Aerodynamic forces at large overhangs.

(3) Severe tendency to vibrate and false brinell.

One American controllable propeller design uses a flat plate thrust bearing with short cylindrical rollers of square section and two separate bushings inside the blade for overhung air forces. Most of the other designs employ a series of angular contact type ball bearings, ground to divide load. Several rows of small balls dividing the load provide larger thrust capacities per pound weight and for the space than can be obtained with one row of large balls. To obtain high thrust capacities, the race curvatures are made to extremely close conformity with the balls. No retainer is now used. The race sections are cut to a minimum for space and weight saving, but introduce serious production problems in maintaining tolerances and roundness.

Load variations and vibration produce considerable working or fidgeting between the bearings and the blade and also on the outside diameters. Severe galling may result. This has been alleviated by slightly looser fits and even more by special plating both on blade and on the bearings, usually a hard material on the blade and a softer thin plating on the bearing bores. So-called anti-galling lubricants or rust proofing have not proved to be useful as the galling is not a true false brinelling or fretting corrosion.

How False Brinelling is Overcome.

False brinelling refers more exactly to what happens at the ball-race contact under the continuous slight oscillations of an automatic propeller. The most effective antidotes are first adequate bearing size to keep the unit pressures down and second complete submersion of the bearings in oil or special greases. A new concept of "brinelling" or "nonbrinell" capacity has been developed in selecting the bearings for the occasional large momentary loads. A surprisingly large step exists between the first permanent surface impression visible under a small magnification and the first measureable depression.

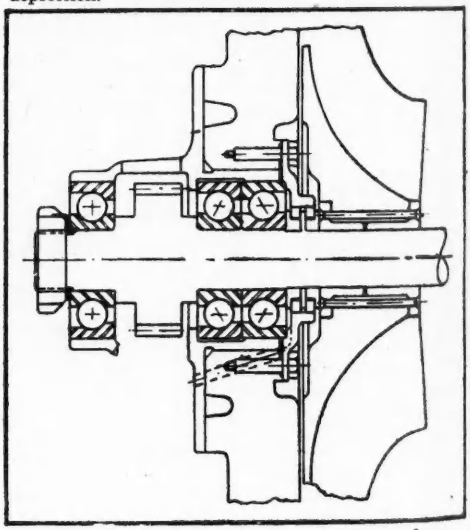


Fig. 1 Typical supercharger bearing layout for a shaft running 36,000 rev./min.

THE LOAD CARRYING CAPACITY OF PLASTIC BEARINGS

DIPL. ING. H. FRANK. (From *Maschinenbau* (*Der Betrieb*), Vol. 21, No. 6, June 1942, pp. 257-261).

By correct choice of material and suitable application of the bearing, the performance obtained with plastic bearings cannot be improved even with the best metal bearings. Synthetic resin bearing materials require fundamentally different handling from that given to metal bearings and this fact must be fully appreciated if successful operation is to be ensured.

In spite of all the efforts which have so far been made to explain the behaviour of plastic bearings, many people are still uncertain regarding the properties of synthetic materials. Reference is often made to the conditions of installation, servicing, and other treatment which such bearings require. Engineers often feel that they have to rely on results of their own tests and experiments in determining the load-carrying capacity. The lack of knowledge is a serious drawback, which prevents them from using the materials with a feeling of confidence, and prevents the use of synthetic materials in cases where they are suitable.

Fundamental Load Carrying Capacity.

It is practically impossible to determine the actual permissible load carrying capacity of synthetic bearing materials without knowing accurately the dimensions of the bearings. From the information which is always available it is possible to determine the approximate permissible bearing load, under which plastic bearing can be subjected, providing care is taken in the design, and lubrication is satisfactory. Bearing failure can usually be attributed to either faulty design or faulty conditions of operation.

A special warning is given against the practice of relying upon a fixed and rigid load value such as the P.V. factor (bearing pressure × rubbing speed). This is an erroneous practice, as actual working conditions can never be calculated because the mutual effect of bearing pressure and rubbing speed differs for each range of load. Hence such values as are given in Table I. can only be considered as guidance values.

TABLE I.

Type of Lubricant or Lubrication	Quantity of Lubricant	Rubbing speed v, m/s	Bearing Pressure p, kg/cm²
"Stauffer" grease	about 6 g/h	0.2 to 1.5	40 to 5
Pressure grease	about 60 g/h	0.2 to 1.5	120 to 20
Drift feed	about 0.1 g/h	1 to 4	30 to 10
Ring lubrication	loose ring	1 to 10	15 to 3
Oil bath (non-pressure)	about 0.5 l/h	3 to 10	50 to 10
Oil pressure	about 13 l/h	3 to 10	100 to 40
Oil pressure	about y0 l/h	3 to 15	200 to 80
Oil pressure	cooled	>4	up to 500 (special design)

The type of lubricant and the quantity supplied to the bearing have to be considered. The quantity and the quality of the lubricant supplied affect appreciably the bearing performance.

The use of hardened and ground shaft journals, the use of solid lubricating rings and other design measures has improved the load performance of synthetic bearings. The load carrying capacity of the bearings can be improved appreciably by using cooled journals, which assist in conducting the generated heat quickly and safely away.

When small rubbing speeds of the order of 0.1 m./sec. are used the specific bearing pressure must be reduced, otherwise, owing to the contact made between bearing surface and journal surface, an increase in friction is to be anticipated. Under these operating conditions satisfactory performance can only be obtained by using grease lubrication.

When the bearing is subjected to oscillating movement and lubricated with grease, and the bearing is designed with 5 to 8 longitudinal grooves running along the whole length of the bearing surface, bearing pressures of 200 to 250 kg/cm² are permissible. When impact load is employed high bearing pressures may not be permitted.

When the operating conditions are intermittent the permissible bearing pressure can be increased beyond the values given above, for under such conditions the heat transfer is more favourable. The heat conductivity affects appreciably the load carrying capacity of the bearing. With small rubbing speeds, bearing pressures as high as 130 kg/cm² are permissible providing the heat transfer results in a bearing temperature not exceeding 90° C. Typical of such bearings are those to be found in crane design for the bearings of rotors, lifting shafts, etc.

The particulars given above refer to closed or full bearings used in general engineering. Half bearings, such as are used in rolling mills of foundries, require different consideration. In such cases, very high specific bearing pressures are permissible because bearing journals are effectively cooled by a direct water spray, and also because the load is transient.

With appropriate bearing design pressures of some 500 kg/cm² are permissible. This is, however, only possible when the design of the bearing is arranged in segments and held together by an outer frame. In bearings of this type the low strength properties of the synthetic resin do not matter, because the bearing lining is clamped tightly together as a whole. This type of bearing should always be used when the bearing load is above some 150 kg/cm².

Fig. 1 shows the relationship between bearing pressure and rubbing speed for plastic bearings. These curves obtained for a bearing reinforced with lamellar inserts (a) and for a bearing reinforced with shaving inserts (b) assume that the bearing design, lubrication, bearing cooling and the attendance are all that is to be desired. Failing this, it is not possible to define accurately the limits of the load capacity of the bearing, and it is necessary when designing and when operating plastic bearings to pay the strictest attention to the fundamental requirements.

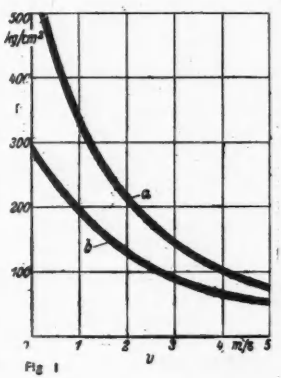


Fig 1

The Choice of Materials.

By changing over a bearing to plastic materials, attention must be paid to the type and structure of the required material, because according to the German Standards (DIN 7701) only a limited number of materials may be considered. These materials and the various designs of bearings have been retained in German Standards (DIN 7703) in so far as they have been used extensively for bearing purposes in the industry[1]. It is to be observed that "wrapped"[2] bearings and pressed tubular form bearings can only be used in special

cases. Bearings which are subjected to dirt and dust, should be made from coarse shavings of waste materials of resin impregnated fabric. These materials have relatively high strength and running properties.

In special cases and with bearings which are of wrapped design the material can be a combination of fabric laminated structure and of shavings. The bearing surface is made from round layers which are pressed into the shaving filler. The mechanical properties of this type of material are high.

Half Circle Bearings for Rolling Mills.

For light and medium bearing pressures of some 250 kg/cm² coarse shaving fillers in moulded form can be used. With high loads the mechanically stronger hard fabric type of filler is recommended. In the same way for high loads, moulded bearings made of coarse shaving filler, having a bearing surface of 10 to 20 mm. made of round " lamella " fabric can be used.

Physical Properties.

The physical properties of the hard fabric plastic given in Table 2 give guidance in establishing the dimensions of bearing shells and bushes. It is fundamentally important to realize that these values give no information regarding the running properties of the materials. The values given are mean values obtained from results having normal amount of scatter, the recommended minimum values have been set down in German Standard DIN 7701.

TABLE II.

	Sheet from coarse fabric	Tube from fine fabric	Shaving reinforcing
Spec. Weight	~1.33	~1.32	~1.30
Resistance to Bending :			
Direction of load :			
Vertical to lamination kg/cm²	1150	1500	600
Parallel to lamination kg/cm²	1120	—	—
Resistance to impact bend'g :			
Direction of load :			
Vertical to lamination cm kg/cm²	30	29	15
Parallel to lamination cm kg/cm²	26	31	—
Tensile strength kg/cm²	550	950	250
Compressive strength :			
Direction of load :			
Vertical to lamination kg/cm²	2930	3500	2700
Parallel to lamination kg/cm²	2330	2500	1850
Modulus of elasticity kg/cm²	~75,000	~83,000	~50,000
Ball hardness kg/mm²	40	40	35
Resistance against Splitting with 7 mm. thk. Specimen kg	~640	~630	~560

The linear co-efficient of expansion is some 25 to 30 × 10-6 per °C. and the heat conductivity coefficient is 0.15 to 0.20 kcal/mh °C. The heat conductivity of plastic materials is, therefore, some 800 times inferior to that of copper, so that the danger of heat accumulation must be counteracted by suitable design. Hard fabric materials can be run continuously at temperatures of 110 °C., and for short intermittent loads, they can run at temperatures of 150 °C. without any undesirable effects.

Constant ageing in water or oil does not affect the material unfavourably, because only through the surface can small traces of fluid be absorbed, thereby causing a small amount of swelling of the order of some 1/100 mm. depth, depending upon the temperature of the bearing when running and also on the wall thickness.

Owing to the satisfactory adherence of the lubricant to the bearing surface the coefficient of friction is very low, so that compared to a metal bearing a 35% reduction in power losses can be obtained.

Design and Bearing Mounting.

When changing over to plastic bearings, it is incorrect to follow the practices employed with bronze bearing shells, as difficulties which would be encountered would impair the usefulness of the bearing or result in bearing failure.

The wall-thickness of plastic bearing shells and bushes have been enumerated in the German Standards DIN 146 and 147. The mean value of wall-thickness is about 10% of the shaft diameter. It is preferable to use the thinnest possible wall thickness.

Small collars or shoulders can be moulded or machined integral with the bearing bush. Hard fabrics in tubular form require satisfactory fillets. In order to remove the initial stresses from the collar it is desirable that that part of the bearing surface which corresponds to the width of the collar is machined with a suitable clearance. Large collars are best made as a separate part. Two different methods of mounting the collars are shown in Fig. 2.

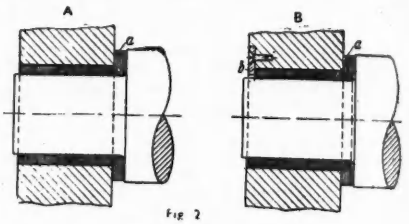


Fig 2

A—(*a*) Floating. B—(*a*) Seated, (*b*) Location.

The necessary tolerances to ensure satisfactory interference or force fit between the outside diameter of the bearing and the inside diameter of the bearing housing are given in Table 3. The tolerances are 5 times greater than those necessary with metal bearings. Split bearings or bearing shells require the same degree of interference for mounting. It is, therefore, desirable to mount the bearing prior to finish machining the internal bore. Undercutting at the back of the bearing shell or bush is not permissible for the whole length of the shell should be supported in the housing.

TABLE III.

Outer diameter mm	Tolerance lower mm	Tolerance upper mm
10 to 18	+0.08	+0.20
19 to 30	0.10	0.30
30 to 50	0.15	0.40
50 to 80	0.2	0.50
80 to 120	0.25	0.70
120 to 180	0.30	0.90
180 to 250	0.40	1.10
250 to 315	0.50	1.30
315 to 400	0.60	1.40

To prevent heat accumulation during operation, it is advantageous to use short bearings having a length : diameter ≤ 1. When long bearings are required it is better to divide them into two halves. The moulding skin or film formed during manufacture at the bearing surface should be completely removed by carefu

(1) Here follows a description of materials suitable for different load applications, together with German specifications, i.e., DIN numbers (Editor).

(2) A method has recently been developed in Germany for coating or wrapping the journal with plastic instead of using orthodox bearing. (Editor).

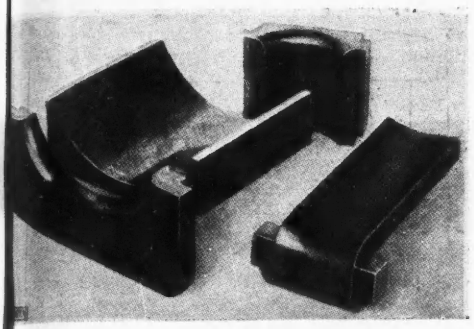


Fig. 3

machining in order to ensure satisfactory adherence of the lubricant to the material.

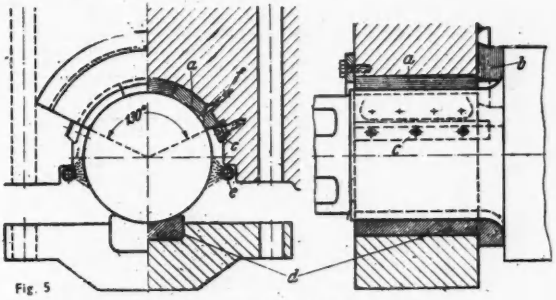
The shaft material should be machined with a smooth finish and should be made from German Standard materials DIN St 60-11 or DIN St 50-11[3] for low bearing load purposes. When bearing loads are high it is necessary to grind and lap finish the shaft surface. If steels such as DIN 34-11 are used they should be case hardened.

Rolling Mill Bearings.

It is absolutely necessary to mount the bearing so that it has a good firm support all round. Only rolling mill bearings subjected to light duty can be used moulded in one piece. In this case the bearing and the collar or flange are moulded integral with one another. In general, the collar is made separate from the bearing body as shown in Fig. 3.

With journals of a diameter greater than 200 mm., segment bearings are preferable. The segments are made from hard fabric, having a special cast steel support or frame as shown in Figs. 4 and 5. That part of the journal enclosed by the segment bearing makes an angle of 130 to 135 deg., including the lubricating pockets.

To ensure satisfactory operation with plastic bearings the bearing clearance must be correct and very much greater than that given to metal bearings. It is especially recommended that the top limits of the I.S.A. tolerances C 11 be used, especially with the use of cellular wool. These clearances may appear to be excessive, but owing to lubricant causing the bearing to swell, the clearance soon becomes normal. A study of the curves given in Fig. 6 emphasizes this fact as shown by the reduction in oil consumption with increase in duration of operation.



Segmented bearing directly embedded in housing.
a Segmented fabric bearing; *b* Flange; *c* Tension strips; *d* Hanging bearing.

Running-in.

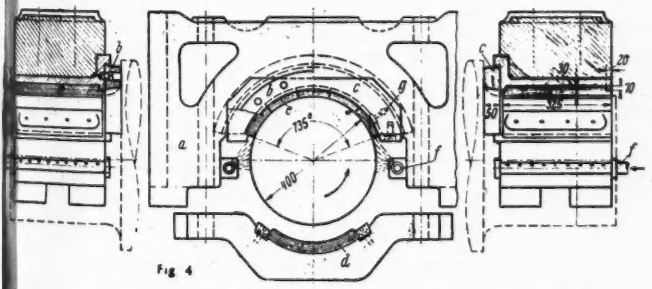
In order to obtain a suitable bearing surface to ensure a margin of safety during operation, careful running-in is essential. The " quality " of the bearing surface is attained by a continuous short time loading of the bearing until the operational load is reached. With each increment of load, the shaft temperature should not exceed 120 to 130°. When this temperature is reached, the load should be taken off the bearing, and the bearing cooled to room temperature. Careful attention during running-in is necessary.

LUBRICATION PROBLEMS.

Bearing for General Mechanical Purposes.

Owing to the bad heat conductivity of plastic bearings, special care must be taken with lubrication and also in the design of lubricating grooves, etc. The loaded half of the bearing must be free of lubricating grooves crossed grooving should never be employed. The lubricant should be supplied to the unloaded part of the bearing (Fig. 7) and mostly through a distribution groove (*a*) situated in the top half of the bearing. The groove (*a*) intersects the annular groove (*b*) which feeds the bottom half of the bearing. The latter is provided with oil pockets (*e*) which are designed to run into the bearing surface at the point of pressure. The corners of the pockets (*e*) and the " mudway " (*f*) as shown at (*d*) should be smoothly rounded.

The grease must be pressure resisting, having a melting point higher than the maximum temperature of the bearing. Oils of pure vegetable or animal base are not suitable for the lubrication of plastic bearings. Best results are obtained with refined mineral oils or special oils.



Segmented fabric bearing with intermediate sleeve.
a Top half of housing; *b* and *c* Flange; *d* Hanging bearing; *e* Bearing segments; *f* Water cooling; Water cooling; *g* Grease entry.

Rolling Mill Bearings.

It is naturally advantageous to cool the journal surface by means of a water spray, which is applied along the whole length of the journal, and also at the points of leading and trailing edges of the bearing. The water quantity depends more or less on the characteristics of the lubricant which is being used, but in general one uses 80 to 100% more water than is used with metal bearings, thereby controlling accordingly

(3) It should be pointed out that in specifications of German Standards St. means steel, the values 50 to 60 refer to tensile strength in kg/mm², while the number 11 means the number of the specification.

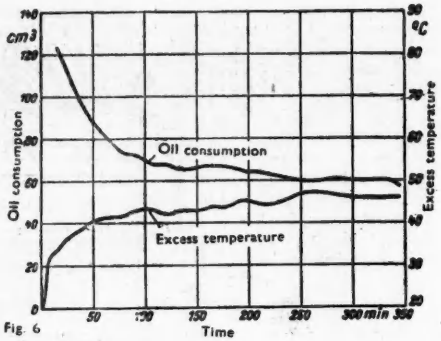


Fig. 6

the bearing temperatures. The water pressure is approximately 2 atmospheres.

Plastic bearings can also be lubricated with grease blocks or pressure grease. Although with high speeds and low loads plastic bearings can be used without grease, increased wear and friction with reduced bearing life will be experienced. In general, the use of grease blocks with satisfactory lubrication properties and high melting point is sufficient. With higher loads it is desirable to use automatic lubrication with pressure grease having suitable lubrication pockets (Fig. 8).

When using block grease and speeds above 1.5 m./sec. it is advantageous to have the cooling water jet arranged in front of the grease entry on to the journal. The water jet arranged between the grease entry and the bearing leading edge is only permissible with low speeds.

Machining and Tolerances.

In the same way as brass or hard wood, plastic material of all structures can also be machined. With sheet plastic it is especially important to pay attention to the lamination characteristic of the material. The material can be turned, drilled, milled, sawn, filed, ground and reamed.

The machining operations should be carried out without cutting fluids, with high cutting speeds, small feeds and with sharp-edge tools. The greater abrasive action of plastic materials causes the tool to become more easily blunt especially with high speed tools, hence it is advantageous to use diamond tools. Cutting speeds are given in Table 4. Feeds should be 0.4 to 0.6 mm. The accuracy of machining need not be held to such close tolerances because owing to the higher elasticity of plastic materials, working tolerances of 0.1 mm. for standard diameters from 10 to 60 mm can be

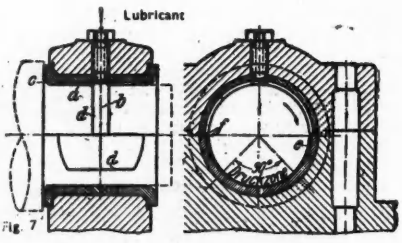
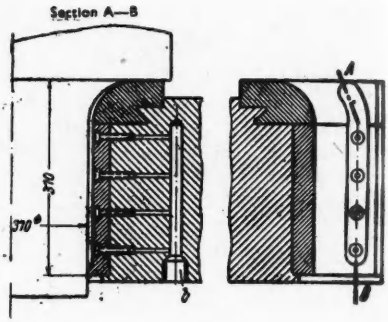


Fig. 7

a Distribution groove; *b* Annular groove; *c* Fillet; *d* Rounded transition to bearing surface; *e* Grease pocket; *f* Rounding of the inside edges of top and bottom half.



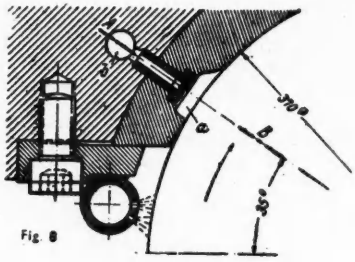


Fig. 8

a Grease pocket; *b* Grease entry.

TABLE IV.

	Tool Material	
	Diamond m/min.	High Speed Steel m/min.
Twining	about 200	about 50
Milling	80 to 120	about 50
Drilling	80 to 100	40 to 70

considered as the lowest limit. Small tolerances of 0.05 mm should only be required in special cases. It is doubtful whether they can be carefully measured and inspected after completion of machining. Hence, the designer should refrain from using greater accuracy than that which is absolutely necessary. The accuracy of moulded components are as follows:

Ranges of size	Tolerance ±
30 to 50 mm.	0.2 mm.
50 to 80 mm.	0.3 mm.
80 to 120 mm.	0.4 mm.

Measurements in line of pressure should be given an additional tolerance of 0.2 to 0.5 mm. according to the size of component.

PORTABLE UNIVERSAL RADIAL DRILLING MACHINE FOR THE ASSEMBLY SHOP

(From *Werkstatt und Betrieb*, Vol. 75, No. 9, September, 1942, p. 221).

THERE are still many operations done by hand which could be done better and quicker by a machine, among which are, for instance, the drilling of holes for splints or for oiling, the drilling of assembled parts, etc. For this and similar jobs the universal drilling machine designed by Messrs. Ganz has become widely known in recent years, particularly in the manufacture of heavy machine tools, as it is mounted on wheels and can be easily taken to the job.

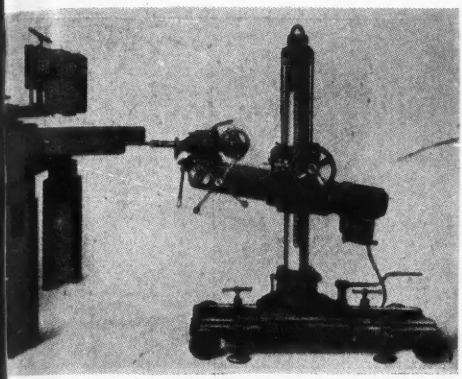


Fig. 1. Portable Radial Drilling Machine, drilling holes in an assembled part.

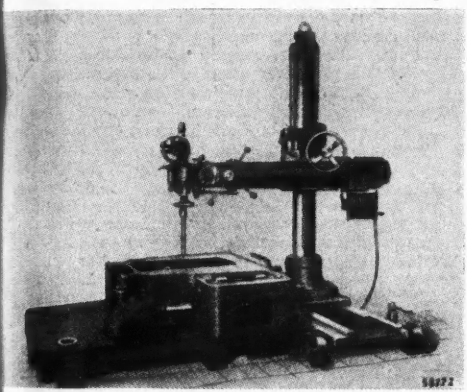


Fig. 2. Drilling holes in machine standard.

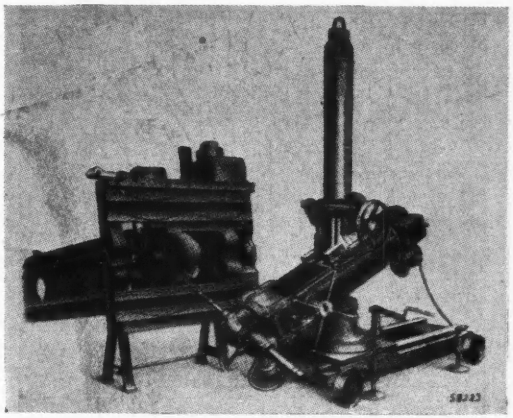


Fig. 3. Drilling holes at inaccessible places.

There are four wheels and the base of the column slides on the machine bed and is clamped in position by bolts. The radial arm and the drill head may be moved vertically by a hand wheel. The weight of the moving parts is counteracted by a balance weight in the hollow column of the machine. The radial arm is movable radially on slides of the arm support, and in this respect the machine is different from the usual type of radial drilling machines where only the saddle can be moved in radial direction on the arm. A special feature is that the spindle and spindle head can be turned 360° round in a plane at right angles to the arm. In addition, the spindle head can be turned between the two sides of the arm, within 180° between an upper and a lower extreme position. It will thus be seen that holes in almost any direction including the vertical and the horizontal can be drilled.

The spindle is provided with automatic feed, fine adjustment and a quick return movement by hand. Holes up to 250 mm. in length can be drilled in one operation. The diameter of the spindle is 50 mm. The cutting capacity is about 40 mm. in steel of 50 kg/mm², the thread-cutting capacity is 1¼". The greatest distance between the centre of the spindle and the centre of the column is 1100 mm.

PORTABLE ELECTRICAL VENTILATOR FOR THE WORKSHOP

By Dipl. Ing. H. Rötscher, *VDI*, Berlin. (From *Werkstatt und Betrieb*, Vol. 75, No. 9, Sept., 1942, pp. 219-220).

Portable ventilators are particularly valuable when temporary ventilation arrangements have to be made. Efficient artificial ventilators must be capable of pumping in fresh air or expelling foul air at different places simultaneously, the volume of air being regulated accurately with dust and vapours eliminated while in the winter months an excessive heat loss due to the expulsion of the air has to be avoided. An important fact is that there must be no sparking if there are explosive vapours or dust. With regard to the actual operation of the pumping equipment it should be possible to employ unskilled labour.

The centrifugal ventilator shown in Fig. 1 was designed to meet the above requirements. It is fitted with bayonet-couplings on both the suction and the pressure sides, to which single or double flexible metal pipes can be fixed. If the ventilator is used for exhausting air a filter is usually fixed on the pressure side and a movable pipe head on the suction side. The purpose of the filter is to retain the dust. This results in a con-

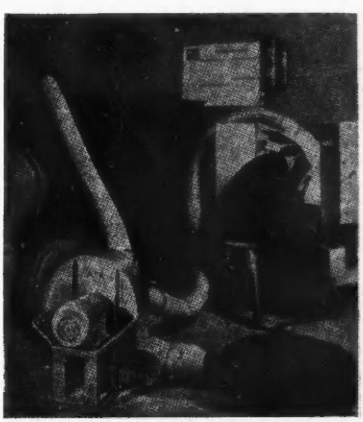


Fig. 1. Portable Electrical Ventilator taking foul air off two working places simultaneously.

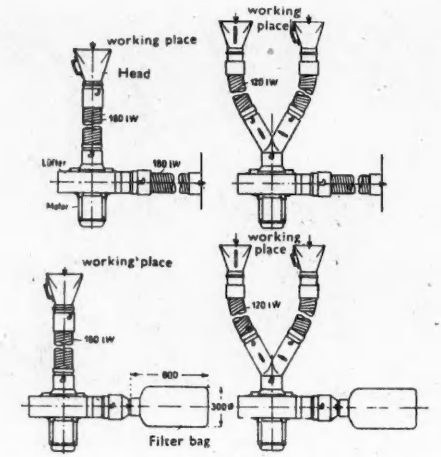


Fig. 2. Different uses of Portable Ventilator.

siderable improvement of the air condition without unnecessary loss of heat. The air must not, however, be returned to a welding shop as in the ship building industry if galvanised iron sheets are being operated on, large hollow iron castings cleaned, or petrol tanks ventilated, as the filters do not absorb gases. Therefore, if the ventilator is used in small premises with air containing a considerable amount of impurities or gases the filter should not be used but a longer pipe connected to the ventilator instead and the pressure air directly led to the outdoor.

Fig. 3. Portable Ventilator used during construction of a boiler.

Couplings being provided on both the suction and the pressure sides the ventilator can be used for pumping fresh air into the premises as well as for expelling the foul air. The latter method is advisable if the air can be expelled quite near where it has become foul.

In many cases the incoming air becomes mixed with impurities before it reaches the workshop or workshops. Sometimes a current of cool air has to be provided and Fig. 3 shows a workman being supplied with fresh air during his work inside a boiler in which, if thought necessary, a forked pipe can be used and the volume of air regulated by a throttle valve.

The use of the ventilator described above (manufacturer: Siemens-Schuckert, Berlin) is further illustrated by Figs. 2a and b. The impeller as well as the casing is welded of steel plates. The entirely enclosed three-phase motor needs practically no servicing. Where explosive gases may occur the impeller is specially designed to ensure freedom from sparks, and the motor is of a special protected type.

Despite its wide range of usefulness this ventilator is simple enough to allow safe operation by an unskilled worker and it has been tried out successfully under difficult conditions in many works.

LIGHT ALLOY PISTONS FOR INTERNAL COMBUSTION ENGINES

By ING. R. KRUEGER, Berlin. (From *Brennstoff und Waermewirtschaft*, Vol. 24, No. 6, June, 1942, pp. 97-101).

THE task of the piston in internal combustion engines is to transmit the combustion pressure through the connecting rod to the crankshaft, to provide the packing between combustion chamber and crank-case, and to conduct away the heat imparted to the piston head. To fulfil all these requirements, the piston must have sufficient strength, small weight, a low coefficient of thermal expansion, and good thermal conductivity.

The important part light-metals can play in piston design has been recognized as early as 1921 when at a competition, sponsored by the Ministry of Transport and carried out in the Technical College, Berlin, two types of piston (Fig. 1 and 2) were successful. Fig. 1 is an electron piston of the firm Griesheim-Elecktron in Frankfurt (Main), Fig. 2 is an aluminium piston by Hellmuth Hirth in Cannstatt.

To-day, practically only A1-Cu-alloys and AL-Si-alloys are used. The aluminium alloys mostly used recently are those containing 12-24% Si, and 1-2% Cu and Ni. The advantage of these alloys is a compara-

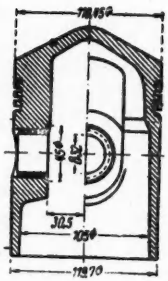


Fig. 1.
Electron Piston (1921).

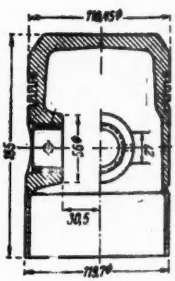


Fig. 2.
Hirth Piston (1921).

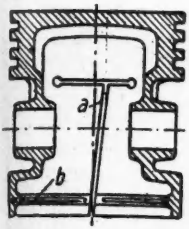


Fig. 3. Split Skirt Piston.

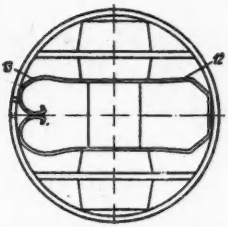


Fig. 4. Piston with expander.

tively low co-efficient of thermal expansion (18 to 20×10^{-6}) and smooth-running qualities. They are less strong than Al-Cu-alloys and of worse thermal conductivity, but of greater resistance to wear. The latter quality is absent in electron-pistons so that these are used for special purposes only, e.g., racing cars.

To do away with the drawback of high thermal expansion it has been tried repeatedly to split the piston skirt. This cheap type of piston for moderate pressures is still being manufactured of Al-Cu or AL-Si alloys. To protect the split parts against failure they are often reinforced by steel insets (b in Fig. 3). The same purpose can be served by an expander (12 in Fig. 4), which lies perpendicularly to the axis of the gudgeon pin. The curved end of the expander (13) lies opposite the split. Another possibility is given by using cast-in steel strips (b and g, in Fig. 5). The splitting is here U-shaped and lies between piston head and the piston skirt, separated from the head by a ring slot. The split t is held by bracket b which can be cast-in steel or cast in one piece with the piston. The MEC-piston (from Mahle, Bad Canstatt) shown in Fig. 7, is similar to that in Fig. 6, but is better from the point of view of heat conductivity. The arrows indicate what course the flow of heat takes through the ribs d to the eye of the connecting rod c. The piston skirt thus remains cool and there is no need for a split in it. The dividing slot n is at the lowest piston ring groove. Fig. 8 shows

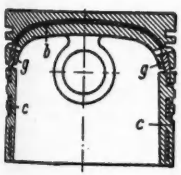


Fig. 5.
Piston with steel bracket.

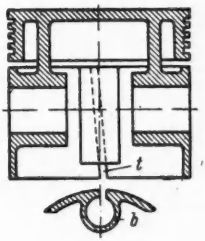
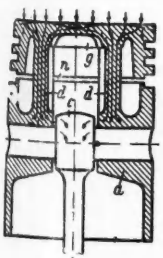


Fig. 6.
Piston with horizontal slot



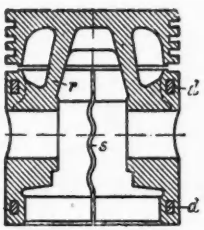


Fig. 8. Piston with steel rings.
Fig. 7. (left) MEC-piston.

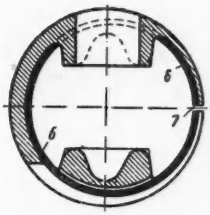


Fig. 9.
Piston with bi-metal ring.

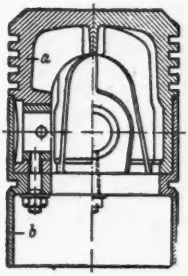


Fig. 10. (right)
Compensating piston.

a split skirt piston with cast-in steel rings d of low thermal expansion which allow a circumferential expansion only, whereby the split s closes up. However, if the ring d after cooling is not tightly embedded by the light alloy, the desired effect cannot be achieved. To obviate this drawback several patents have been taken out. One, by A. Debelak, Vienna (DRP 566738) for pistons with longitudinal slots (7 in Fig. 9) consists of a cast-in ring (6 in Fig. 9) which, due to compensating effect contracts the piston when hot.

The next stop in piston development was to use the compensating (bi-metal) piston, where the head and piston skirt are made of two different metals, say aluminium and cast iron. In this way the low weight of aluminium and its good thermal conductivity are coupled with the high wear resistance and low thermal expansion of cast iron. Fig. 10 is such a piston of the early development (1921) by Hellmuth Hirth ; the aluminium crown a is flanged to the cast iron skirt b. Figs. 11 to 16 show variations of this type of piston. Fig. 11 shows two possibilities of a screwed-in-head piston. Fig. 12 (by H. Chandler, New York) shows

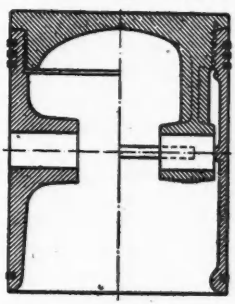


Fig. 11.
Piston with aluminium head.

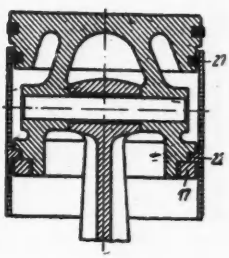


Fig. 12.
Compensating piston
with screwed in ring.

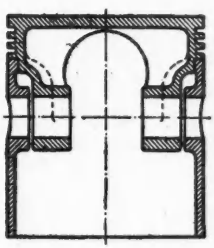


Fig. 13.
Compensating Piston for
bolt-connection.

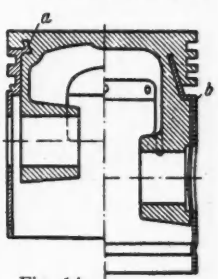


Fig. 14.
Piston with cast-in guide
surface.

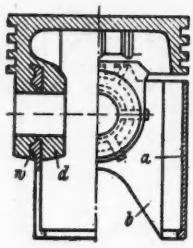


Fig. 15. Koch-piston.

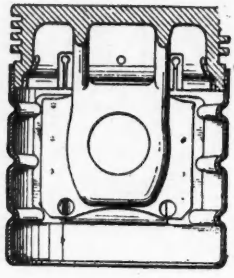


Fig. 16. Compensating piston of General Motors.

how a thin cast iron cylinder with a ring in the form of an inner rib 22 provides a means of fixing to it the aluminium head and ring band by means of the lock nut 17. Ring 27 seals the crown against the skirt. A very simple compensating piston is shown in Fig. 13. The two parts are held together solely by the gudgeon pin. For economical reasons it has been tried to cast the two parts of the compensating piston together. In Fig. 14 two varieties (a & b) of this type are shown. Due to different thermal expansions of the two materials they work against each other constantly, which ultimately leads to a loosening of both parts. To avoid this, the length along which the two materials are joined must be a minimum; the joint must be elastic and out of the

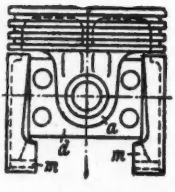


Fig. 17. Invar strut piston.

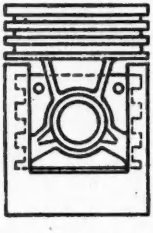


Fig. 18. "Broad-plate" piston.

range of higher temperatures. A piston designed according to these principles by Dr. Ing. E. Koch, Stuttgart, is shown in Fig. 15. The cast iron part has two curved surfaces a, joined by flat sides b, the latter being cast into the bolt-eyes d. A similar piston has been manufactured by the General Motors Corp., Detroit (Fig. 16). Iron plates are cast into the bolt-eyes and connected by spot welding to the steel piston skirt.

A great step towards the elimination of the thermal

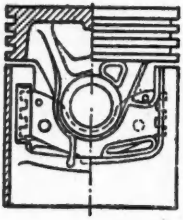


Fig. 19. "Low-strip" piston.

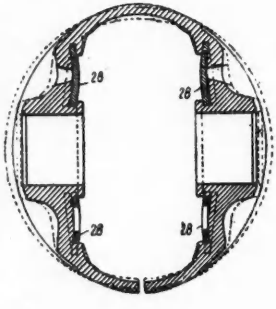


Fig. 20. (right) Autothermic piston.

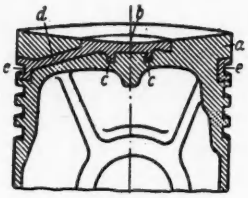


Fig. 21. Diesel piston with head plate.

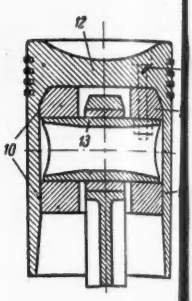


Fig. 22. (right) Diesel piston with screen ring.

expansion was made in 1923 by Adolph Nelson, of Detroit. Fig. 17 shows the invar strut piston. The low coefficient of expansion of invar steel keeps the expansion of the piston down. However, the invar plate has shown a tendency to separate from the light-alloy components, and, therefore, the latter had to be designed as a complete body. This type, the "broad plate" piston is shown in Fig. 18 (made by Mahle in Canstatt). Lately, alloyed or unalloyed steel plates (coefficient of thermal expansion 12×10^{-6} and 15×10^{-6} respectively) have been cast-in. The piston is known as the "low-strip" type. Similar in design, but quite distinct in its working is the autothermic piston. Here the cast-in plates (28 in Fig. 20) are of nickel-free steel, which together with the aluminium body of the piston form a compensation member. The shaded cross-section Fig. 20, represents the piston in the cold state, the dotted lines show it when hot.

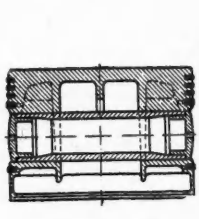


Fig. 23. Cast aero-engine piston.

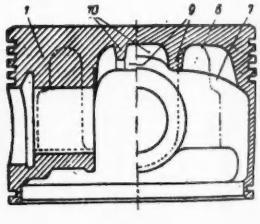


Fig. 24. Pressed aero-engine piston.

The pistons of high speed diesel engines and aero-engines are especially highly stressed, mechanically as well as thermally. At the piston head melting phenomena or cracking can occur. To avoid this the firm Mahle, Bad Canstatt, uses a cast-in head plate b of nickle-iron or bronze which has the same thermal expansion as the piston a but greater heat resistance (Fig. 21). The plate b is connected by arm d with ring e which is grooved for the piston ring.

Diesel pistons are mostly manufactured from Al-Si alloys by casting or pressing. In the pressed piston shown in Fig. 22 special bolt-eyes 9 and 10 are provided which are bolted (7) to the pressed body. Pistons for aero-engines have been manufactured in the past by casting (Fig. 23), to-day exclusively by pressing or forging. The

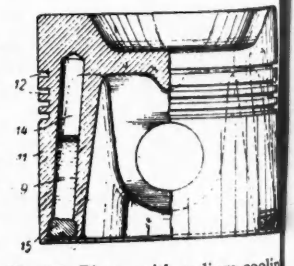


Fig. 25. Piston with sodium coolin

former process is favoured in Germany, whereby high class Al-Si alloys are used. Fig. 24 shows a pressed aero-engine piston of the Elektron Co., Stuttgart. The ribs 7, 9 and 10 are stiffeners, and simultaneously serve the purpose of conducting the heat away. Further improvement in the latter mentioned respect is due to an American patent (No. 1841796, H. Edwards, Detroit) utilizing an easy melting salt or metal. Fig. 25 shows such a piston for diesel or aero-engines, having peripherally distributed chambers (14) filled with the cooling agent 9, say sodium, and sealed by a screwed plug 15. During the compression stroke the cooling agent which is sprayed against the piston head, melts, and transmits the heat during the following downward stroke to the colder bottom part of the piston.

LIQUIFIED GAS FUEL FOR DIESEL ENGINES

By F. DREYHAUPT. (From *ATZ*, Vol. 45, No. 8, April 25th, 1942, pp. 201-207).

INVESTIGATIONS in this field have been carried out by Neugebauer and Wachsmuth and by Stoll. In both cases a practical solution of the problem of adopting Diesel engine for liquified gas fuel was obtained by blending the fuel either with 12% (by weight) lubricating oil or with 20-30% diesel oil. An obvious difficulty in operation with liquified gas would be due to its great volatility; already at 1 atm. pressure and 20-30° C. temperature the fuel vaporizes and the vapour bubbles formed may hinder smooth fuel pump operation.

Fig. 1 shows schematically the system developed by Neugebauer and Wachsmuth. Principally it consists of an over-dimensioned feed pump (gear-pump) and two de-gasing by-passes. Efficient scavenging of the pipes and the pump reduces the quantity of vapour bubbles in the system, and—what is more important—provides uniform bubble distribution.

Fig. 2 illustrates Stoll's method. About 10% of the liquified gas is passed through the throttle valve (5) to the cooling jacket (4), where the heat of vaporization is utilized for cooling the main liquified gas stream flowing through the pipe (2). This pipe itself serves as a by-pass for the vapour bubbles, the circuit being completed at point 6. A small quantity of oil fuel is injected through the pipe (3). The evaporated portion of the fuel passing to the jacket is recovered by readmitting it to the engine through the air inlet.

Apart from the fact that compared with C.J. engines the beginning of fuel injection must be advanced by some 15-20° crank angles in both systems, nothing was known about the processes taking place in the injection system and the engine cylinder, and the main object of the investigations described in this article was to clarify some of these points.

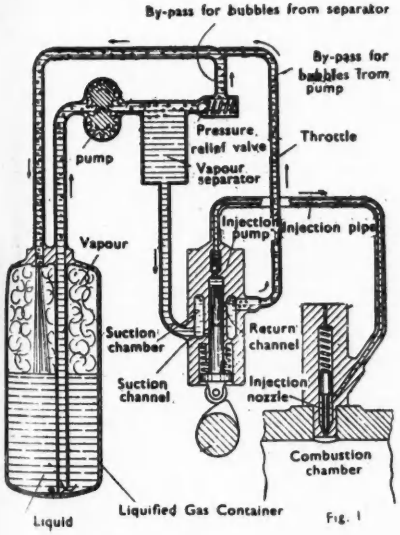


Fig. 1

Injection System.

The fuel is supplied to the pump from a container seated on a scale pan (Fig. 3), in which the pressure is maintained at about 12 atm. by means of compressed nitrogen. This container is filled with the fuel from the provision flask (Fig. 3), and the arrangement permits accurate measurement of fuel consumption. Since the fuel is forced into the pump invariably by the pressure in the fuel container (12 atm. in this case, and the vapour pressure in the systems Fig. 1 and 2), it is essential to make some simple alterations in the packing of the pump to suit these conditions.

Test Engine.

For the test purposes a Ricardo engine with a "Comet I" type turbulence chamber head (Fig. 4) was employed. The stroke volume of the engine was 1590 cm³, the compression ratio 17.3:1, and turbulence chamber and parts made up of 75% of the total clearance space.

To obtain uniform self ignition it was essential to subdivide the turbulence chamber throat into a number of narrow channels, which are brought to a high temperature during expansion, and in turn, heat up the incoming air during the next cycle. Incidentally this method has been known since 1935, for other type of fuels.

Test Results.

With the arrangement the engine could be run in the whole speed and load range (up to 2200 r.p.m.) with pure liquified gas fuel. The change of load was easily followed by the engine, which proved that C.J. operation is feasable with this type of fuel, though for starting up diesel oil had to be used.

Fig. 5 shows the indicator diagram for liquified gas fuel. Fig. 6 shows fuel consumption and exhaust gas temperatures, and it should be remembered that liquified gas fuel has by no means been utilized to full advantage in the test engine, and that therefore a further 10% improvement can be expected from future development of this type of engine.

Fuel Compressibility, Partial Vaporization in Nozzle, Nozzle Dimensions.

During the trial runs it was found that the quantitative flow of fuel through the nozzle is considerably less

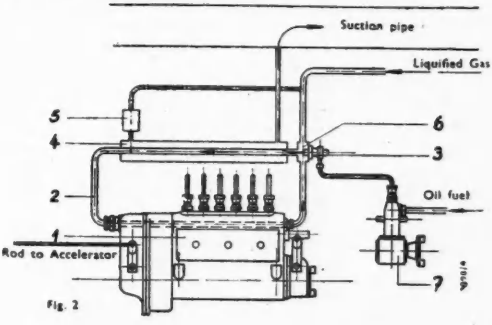


Fig. 2

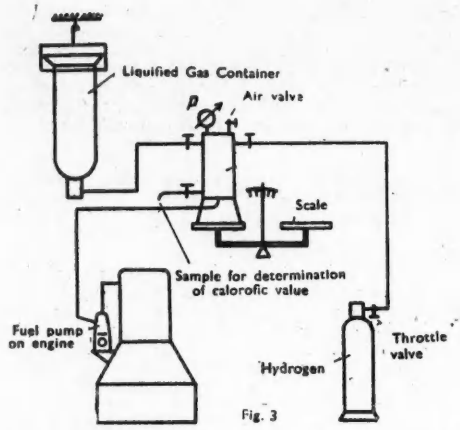


Fig. 3

than with oil fuel. This is probably due to partial vaporization of the fuel before it reaches the nozzle, so that not a liquid but a mixture of liquid and gas is flowing through the nozzle. This could be seen also from the prolonged injection period which continued for some time, even after the pumping stroke. Too small a nozzle diameter alone is, however, not responsible for this phenomenon, it is also necessary that an adequate fuel quantity be stored in the pipe before the nozzle. This is possible with liquified gas as it has a compressibility many times that of oil fuel.

The explanation that the prolonged injection is a consequence of the smaller velocity of sound in the liquified gas corresponding to its high compressibility does not hold good. During the test a large pressure relief valve was fitted in the injection pump to deal with the compressibility effect and which prevented the re-opening of the nozzle due to pressure waves in the tube. The fuel consumption was unsatisfactory, but these troubles were eliminated when a large nozzle was employed. Fig. 8 shows the required nozzle opening section for both oil and liquified gas fuels.

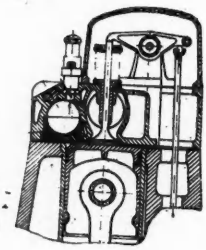


Fig. 4

Ignition Lag, Injection Delay.

The ignition lag was found from the tests to be about 14-18 degrees crank angle (Fig. 9), that is 1.67×10^{-3} secs. at 1500 r.p.m. This value is of the same order as the ignition lag of oil fuels. Nevertheless, Neugebauer and Wachsmuth found that the beginning of the pumping stroke must be advanced by some 20 degrees compared with oil fuel. This must be due, evidently, to a longer injection lag for which the high compressibility of liquified gas is responsible, and due to sluggish filling of the pump in spite of the high pressure maintained in the fuel tank.

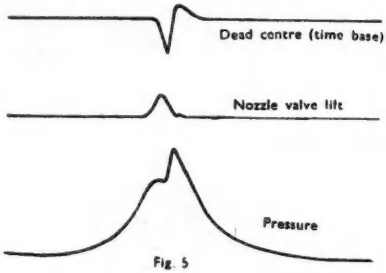


Fig. 5

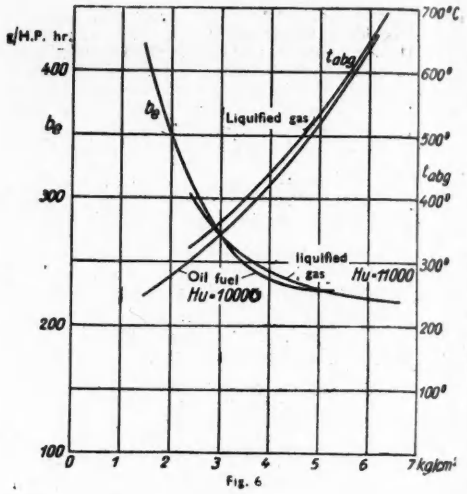


Fig. 6

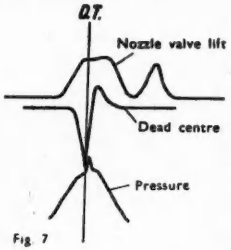


Fig. 7

Filling of the Injection Pump.

The high compressibility of the fuel is also responsible for the following phenomenon: with unaltered pump adjustment the opening of the valve needle is suddenly delayed by 10 degrees crank angle for a load of about 4-5 kg/cm² (Fig. 9). The change

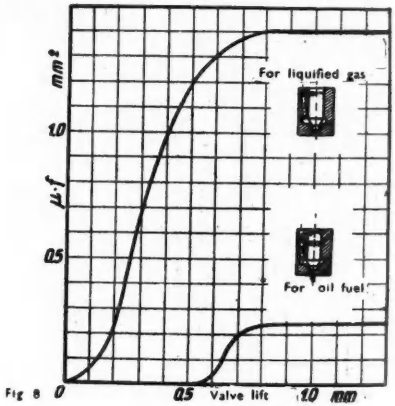


Fig. 8

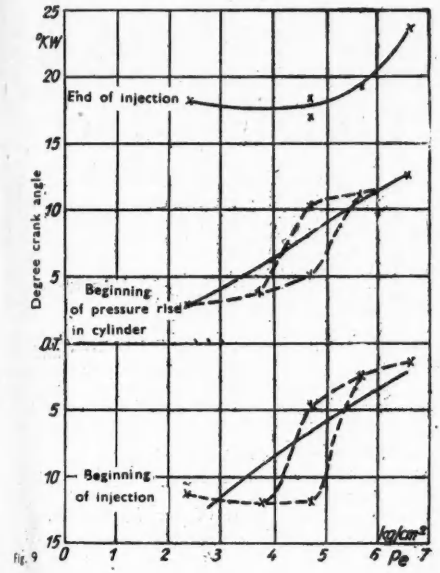


Fig. 9

occurs in such a manner that during the transition period alternate early and late injections take place. Ignition follows, however, with an unaltered time interval (Fig. 9). On the injection diagram, Fig. 10, this phenomenon appears as a gradual disappearance of the first undulation of the valve lift accompanied by an increased fuel injection. This means that with a larger fuel quantity injected the pump has a longer "idle phase" before actual pumping starts. Because of the above mentioned characteristics, it was found necessary to use larger fuel pumps than with oil fuel. A pressure relief valve in the circuit was still retained.

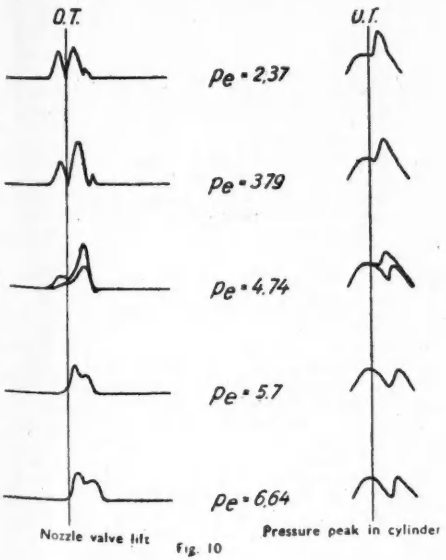


Fig. 10

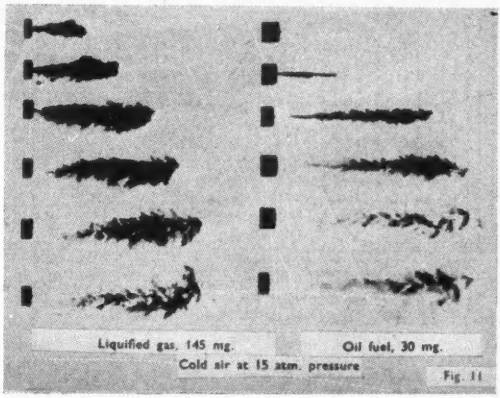


Fig. 11

Fuel Jet Investigations.

In a specially designed container the fuel jet characteristics were investigated. Fig. 11 shows the jet obtained with liquified gas (left) when the air pressure was 15 atm. and the pumping pressure 110 atm. The right hand side shows the jet when oil fuel is used, the pumping pressure being in this case 150 atm. The much greater angle of cone with liquified gas is apparent from this figure. When a plasticene disc was held at 5 cm. from the nozzle no indentation was observed, even after 200 injections, while in case of the oil an indentation was noticeable already after a few injections This shows that the jet of the liquified gas has no core with a penetrating power. Although this might be partly due to the nozzle and valve arrangement (Fig. 8), since a valve with a sharp cut off was used in a large diameter nozzle. However, this alone does not explain these characteristics and further experiments are being carried on to clarify this point.

In Fig. 12 the penetration in mms. of the jet is plotted against the crank angle. Oil fuel has a much steeper rise, although only 30 mg. of the oil was injected, against 145 gms. of liquified gas. This illustration, too, shows the lack of penetrating power of liquified gas fuel jets.

Investigations of Injection Process on a p-H Diagram.

The p-H diagram is particularly suited for investigations of the injection process. Fig. 13 shows this schematically. Since the specific heats of various fuels

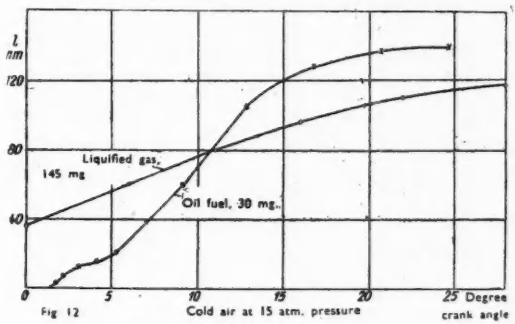


Fig 12

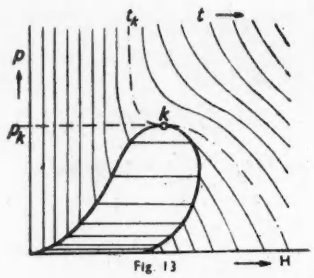


Fig. 13

do not vary greatly, at least as a first approximation, various fuels can be examined in a single p-H diagram, provided a scale of the approximate situation of the isothermal lines is included in the graph (Fig. 14). The pressure drops from the pumping pressure to that in the cylinder, which can be represented by a vertical line, since H remains constant.

Of importance is the position of the left hand side boundary line of the fuel (Fig. 14). If, for instance, the fuel is heated to 130° C. in the nozzle and then expands to 41 atm. following injection then with an Octane fuel this takes place only in the liquid phase. The same applies to oil or benzine. Even with Butane the boundary line is not exceeded. With Propane, however, this is not the case (Fig. 14). Therefore, if the fuel

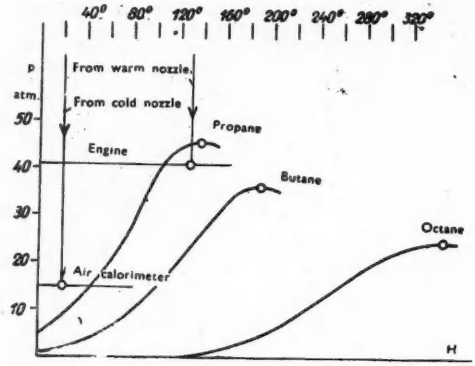


Fig 14

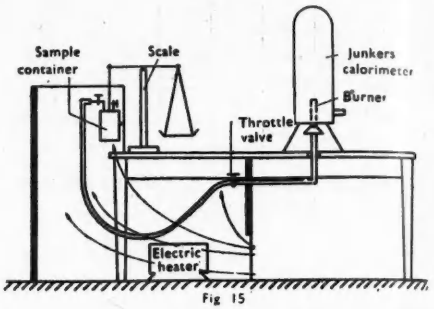


Fig 15

contains an appreciable amount of Propane and small quantities of some low hydro-carbons, then a partial vaporization will occur in the nozzle. Only at a much lower injection temperature, e.g. (20°C.) would vaporization be prevented, even at 15 atm. pressure.

Calorific Value of Liquified Gas.

The determination of the calorific value of liquified gas is not quite simple. For the pilot ignition type of engine the calorific value of the *liquid* fuel must be determined. A Junkers Calorimeter was used for this purpose. As, however, vaporization started already in the container before the fuel reached the burner, the heat of vaporization was taken from the ambient air. Therefore it was essential to separate burner and container so that only gaseous fuel was supplied to the burner. The calorific value of this is determined in the usual manner and the heating value of the liquified fuel determined by allowing 100 kcal/kg for vaporization.

The actual arrangement of the apparatus is shown in Fig. 15. The container must be heated from the outside, as otherwise due to the cooling effect of vaporization a layer of ice would form on its outer surface. This would interfere with the determination of the fuel quantity consumed by the burner. A long flexible piping is used between container and burner, which has to be heated at the lowermost point to a slightly higher temperature than that of the container. Hot air is used for heating.

MEASUREMENT OF IMPURITIES (METAL) IN DIRTY OIL

By H. GRAFF and L. NENNINGER. (From *ATZ, Automobiltechnische Zeitschrift*, Vol. 45, No. 19, October 10th, 1942, pp. 523-525).

OIL used in engines contains varying amounts of metal impurities originating in the first place from cylinder and piston ring wear. A quantitative analysis of these impurities is, for many reasons, desirable. In the following a method is described which can be carried out with moderately simple equipment.

One difficulty of such analyses is to separate the small metal flakes from carbon and to estimate their weight. Spectrographic methods, in particular emission spectrum analysis seems to be a helpful means for such work since it is a comparatively quick method, especially if a large number of oil samples have to be analysed.

A quartz spectrograph, Qu 24, with a " Feussner " type spark generator is used. The spark can be easily adjusted to suit the electrode. For the photometric analysis of the spectrum a Zeiss spectrum analyser was used.

The first step is to separate the metal impurities from the carbon which is always present in dirty oil. The simplest way of doing it is by burning a known quantity of oil in oxygen ; the organic substances evaporate and the residue is oxide of the metals. The powder like residue weighs about 10 mg. if 10 gms. of oil are burnt. This residue can now be analysed after a reference substance, pure coal powder, has been mixed with it. Much of the accuracy of the measurement depends upon the efficiency of this mixing.

Test analyses were made with samples prepared in this way. Hollow carbon electrodes and platinum electrodes with a cup shaped top were used. In both cases the duration of the test was about 30 seconds from the instant the current was switched on. To obtain a reference line for quantitative determination of the substance, magnesium of a known and constant quantity was added to the coal powder.

To improve the accuracy of the test another method of separating the metal from oil was adopted. The oil from the engine was filtered through a porous pot. The residue is made up of metal flakes and some carbon. The metal is separated out by dissolving it in an inorganic acid, usually concentrated nitric acid. As a reference substance nickel nitrate was used, since nickel has a number of lines in the ultraviolet region,

and cannot be expected to appear below the range of lines of the metal impurities.

Experiments show that tests made with oil taken after 200 hours running in single cylinder engines of 1.0 to 2.5 *l* stroke volume contain about 100 mg. iron, 20 mg. copper, 10 mg. aluminium per 10 c.c. dirty oil.

On the basis of the experiments a more accurate method of anaiysis was developed as foliows :

100 c.c. of dirty oil is measured out and centrifuged in an ultra-centrifuge. The oil is poured off, mixed with benzine and filtered through a porous pot. The residue from the centrifuge is treated in a similar manner. Several lots of benzine are then added to the residue to make sure that no oily substance is left behind. The metal is then dissolved out of the residue by 25 c.c. hot concentrated nitric acid. The solution is boiled down to about 1 c.c. and mixed with 1 c.c. nickel nitrate solution of known strength and composition. For comparative purposes quantities of the expected impurities are measured out and added to 1 c.c. nickel nitrate solution and a separate analysis of this is prepared. In this solution used for comparative purposes all impurities can be represented at once, as they have little mutual interference.

Accuracy.

To check the accuracy of the method weighed quantities of the individual metal in powder form were mixed to oil and then treated in the above described manner. The mean accuracy was found to be $\pm 4\%$. Allowing for the less accurate preparation inherent in the use of dirty oil, the actual analysis is believed to have an accuracy of $\pm 5\%$.

The lead content in dirty oil depends greatly upon whether doped fuel is used in the engine or not. If not, the lead content is very small and originates principally in the bearings.

Only metals which combine chemically with the oil to form organic compounds are lost by the analysis. With this method fractions of milligrams can be determined within the mentioned limits of accuracy.

THE CONSTRUCTION AND PROTECTION OF MODERN GRIDS

(From *Elektrotechnischer Anzeiger*, Vol. 59, No. 13, 24th June, 1942, pp. 225-232).

To insure an uninterrupted power supply to industrial plants, individual industrial power stations are usually linked up with the transmission lines of public power supply systems. The short-circuit impedance of public power stations is usually fairly high, due to the length of the high tension transmission lines and to the transformers connected therewith, compared with that of industrial power stations. It sometimes becomes necessary, therefore, to reduce the thermal and dynamic stresses on switchgear and other parts by means of special devices to insure a high reliability of service. The following rules should be observed at the lay-out of grids containing both public and industrial power stations.

Transformers linking up the public grid with an industrial power plant should have about 10% short-circuit voltage. The possibility of voltage regulation has proved valuable, the limit of $\pm 15\%$ covers most working conditions. Sudden current surges over 100 KA should be avoided. The dimensions of the bus bars, apparatus and connections must be sufficient to meet the thermal and dynamic stresses during short-circuits. The right choice of the voltages for generation, distribution and supply is of great importance. Generators and grids should be provided with adequate and reliable relays and protective devices. For consumers supplied with high tension, a radial distribution system with or without open ring connections is an advantage. In certain cases choke coils may be inserted at the junction of bus bars and out-going branch lines.

To protect against surges, a rapid disconnection of the part of the grid affected with the fault by high-speed remote relays, or the splitting up of a certain part of the grid, has proved the best solution.

The general lay-out of a high-tension grid is of the utmost importance as far as reliability is concerned ; additional extensions, changes, etc., which might occur at a later date are to be taken into account. Experience shows that certain kinds of grids are especially favourable. In case the voltage of 6 KV, which is the voltage supplied to the consumer, is too low for distribution of large powers, a distribution voltage of 30 KV may be more economical. By using transformers 30/6 KV with a short-circuit voltage of $7\frac{1}{2}\%$ at the load centres of the grid, switchgear of a capacity of 400 MVA and less can be used.

Apart from their importance for limiting short-circuit currents, relays are indispensable for the protection of grids and machines. Devices using relays to switch off faulty sections of the grid or single consumers insure the maintenance of supply and operation in all the parts of the system with the exception of the section directly affected by the fault. Though the total cost of protective gear is high, it is small in comparison with the value of the equipment protected, and with the cost of the damage and of the lost production which might otherwise be occasioned. Relays are increasingly used with industrial plants to reduce the damage caused by short-circuits or by double earth faults.

Currents due to earth faults are usually compensated by Petersen coils or similar devices, which, in addition, provide protection against excess current through failure of insulation. By splitting up the grid in sections as well as by compensating individual sections of the grid, the reliability of the whole system can be greatly increased. Also protective devices against excess voltage became indispensable in modern grids.

The control of the system is directed from a station where the conditions prevailing in the whole system can be watched, and from where orders are given for all the switching operations throughout the grid, due to increasing or decreasing load or to other reasons. The operation on the central switchboard is facilitated by self-recording apparatus and by a luminous picture of the system, which immediately shows if any fault has occurred.

Small and medium size consumers are connected to the low-tension grid. In general, low-tension grids and the distribution circuits connected to tnem have to meet the same requirements concerning reliability as in the case of high tension. For larger industrial undertakings with a great number of medium size motors between 20 and 100 KW, a three-phase power supply has proved the best. The lighting supply is separate and there is another 220 V grid for this purpose. As a rule, 380 V are used in works with many small motors driving machine tools. In this case the energy for lighting can be easily taken from a line and the neutral wire. Of all the distributing systems tne importance of the interconnected grid is steadily growing due to its high reliability of service. As a whole the following can be said about the different types of distribution systems :

The tree system of distribution is of comparatively

low reliability of service but it can be easily controlled. There is no difficulty in detecting faults, which, consequently, can be quickly repaired.

The ring systems keep up the supply even if one of the feeders is disconnected. They are still easily controlled ; yet it is more difficult to detect faults. The reliability of service can be increased by interconnections and by cross connections between the rings of the system.

The star system is simpler and of higher reliability than the interconnected ring system. Moreover, its reliability can be increased by interconnections, which, however, increase the difficulty of locating faults.

The double-star system has a still higher reliability which can be further increased by interconnections. The location of faults is still comparatively easy.

The most reliable of all is the interconnected system. A fault occurring in one of the feeding points seldom invokes the disconnection of a section of the grid. Yet its control is rather difficult and requires special control of blown fuses. The high reliability is, therefore, obtained at the cost of a difficult supervision.

There are no general rules whatever for the choice of the system for the lay-out of new grids. The system to be used is merely determined by the number, kind, and size of consumers and by their location within the area of supply. To limit short-circuit currents it is advisable, however, to split up the low-tension grids into sections, taking into account the power consumption of the consumer involved. Care should be taken to have the transformers not exceed the size corresponding to the assumed short-circuit load. Reliable fuses for selective protection are most important for low-tension grids. For the tree system of distribution, the high capacity fuse with short time-lag has proved of high value ; on the other hand, selective fuses corresponding with the cross-section area of the interconnections they protect, should be used with interconnected systems.

LEAKAGE CURRENTS, THEIR CAUSE AND PROPERTIES

By RICHARD VIEWEG and HANS KLINGELHÖFFER, Darmstadt. (From *Elektrotechnische Zeitschrift*, Vol. 63, No. 19/20, May 21st, 1942, pp. 237-241).

LEAKAGE current is an electrical current passing between 2 points at different potential on the surface or in the upper layers of an insulator, the surface of which is covered with dust, soot, moisture, etc. As leakage currents arise only after the insulator had been subjected to electrical voltage for a certain period, electrical stresses might be assumed to be the cause of such currents. Careful investigations proved this assumption to be entirely wrong. Electrical resistance actually increases when the material is subjected to electrical pressure.

Leakage currents following ignition sparks. Solid organic chemicals subjected to the heat of electrical sparks, as occur in certain low tension switches, might eventually be carbonised and become a conductor of electricity. The " spark resistivity " can be measured by maintaining sparks between two electrodes on the material to be tested and by counting the number of sparks passing over the surface of the material, before they begin passing partly or totally through the burnt out path on the surface. Fig. 1 shows a spark on its way through the gap first passing through the air and then, at some point between the electrodes, passing on the surface of the plastic itself through the path burnt out by the heat of the sparks.

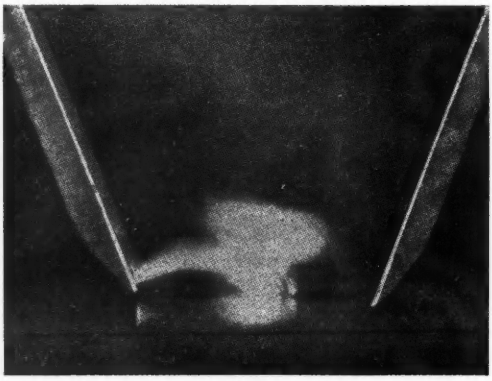


Fig. 1

If the surface is partly covered with dust, soot, etc., a comparatively low voltage may be sufficient to produce the first spark between the electrodes. A leakage current will pass along a path once burnt, even after the surface is cleaned.

It is not certain whether all the leakage currents begin in this way, but it is certain that many of them do. Consequently, leakage currents may be largely reduced by suitably shaping the material and by using a material of high spark resistivity. To satisfy the first condition care must be taken not to allow water to condense in places facilitating the passage of leakage currents. Ribs should be put wherever necessary between the two electrodes to increase the length of the leakage path. The question of material is more complicated but it is shown that there are two groups of materials—safe and unsafe—as far as leakage currents are concerned.

Investigation of the difference between materials liable to conduct leakage currents and materials free from this property gave the following results : Similar

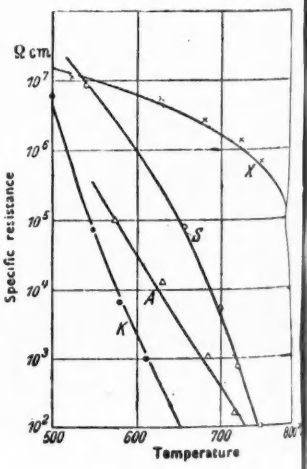


Fig. 2

Ohmic resistance of the ash of plastics as function of their temperature.

X for Plastics Type X.

S for Plastics Type S.

K for Plastics Type K.

A, Analine resins.

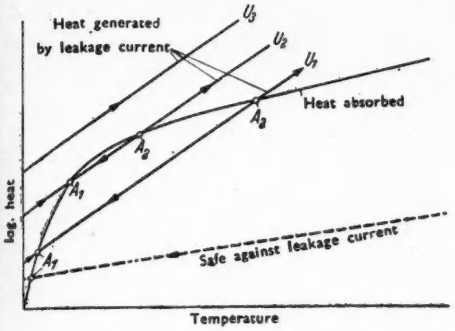


Fig. 3

sparks do not heat all materials to the same degree, the difference being due to the different heat conductivities and the different specific heats of the materials concerned. But this fact proved of negligible influence. Of much greater importance is the ohmic resistance of the product of combustion of the material as function of its temperature. Fig. 2 shows that the ohmic resistance of the ash of organic chemicals rapidly decreases as their temperature increases. This is the reason why the burnt out path on the surface of the insulator becomes a good electrical conductor at from 700° to 800° Centigrade.

Fig. 3 shows the heat produced by sparks from different voltages U_1, U_2, U_3, as function of the temperature. The heat produced by the sparks is dissipated through heat conduction, which is proportional to the temperature T, and by radiation, which is proportional to T^4. Equilibrium between the heat generated and the heat dissipated is possible only at the points of intersection of the curve representing the absorbed heat with the curve U representing the generated heat.

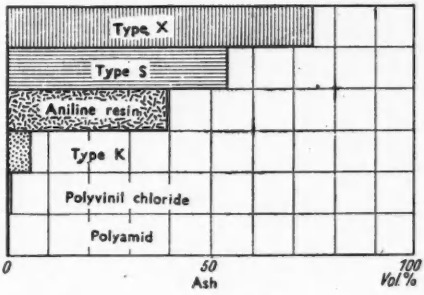


Fig. 4

Some organic chemicals possess a very steep resistance curve yet prove very good as far as leakage currents are concerned, e.g., Type K, Fig. 2. This fact is due to the extremely small volume of ash compared with the volume of the material. The material evaporates to the greatest extent, and though the ash is a good conductor its volume is practically negligible (Fig. 4).

CENTRIFUGAL CONTACT GOVERNOR FOR UNIVERSAL MOTORS

By M. VOEGE, Hamburg. (From *Elektrotechnischer Anzeiger*, Vol. 59, No. 10, May 13th, 1942, pp. 218/20).

VARIATION of speed with load is a great disadvantage of fractional horse-power universal motors. It is usual to provide the field winding with trappings in order to attain approximately the same speed characteristic for d.-c. and a.-c. Various regulator designs have been applied in order to eliminate the variations of speed caused by variations of supply voltage, load, change of supply system (a.-c. or d.-c.).

Speed regulation by means of a centrifugal brake comes into action as soon as normal speed is reached and absorbs the excess torque. This kind of regulator has the disadvantage of waste of energy and heat production.

Centrifugal contact governors which are to be described in this article have proved to be useful. They maintain the current proportional to the load on the motor, as soon as the desired speed is reached, by inserting a resistance intermittently into the circuit by a contact closed by a centrifugal force when the speed exceeds the normal value. Opening and closing of the governors are rapid.

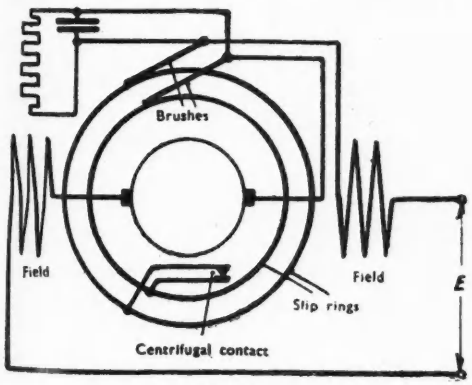


Fig. 1

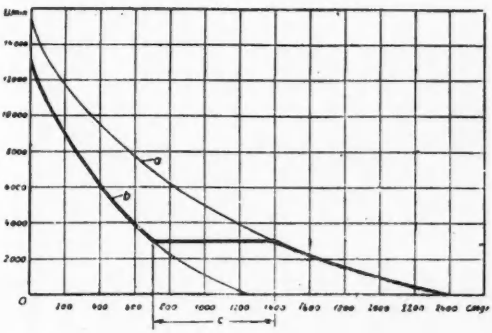


Fig. 2

a Characteristic of the motor when the centrifugal contact is closed; *b* Characteristic when the contact is open; *c* Range of constant speed.

Fig. 1 shows the connections of a universal motor with a centrifugal contact governor. The circuit includes the two slip rings, which are bridged by the centrifugal contact of the governor. In order to avoid sparking and to prevent wear of the contacts a condenser is connected across the slip rings. With large currents a resistance is inserted into the circuit placed between the slip rings as shown in the diagram. This resistance is short-circuited when the contact is closed.

The influence of this procedure on the torque—speed characteristic of the motor may be explained by diagram, Fig. 2. Curve (*a*) is the speed characteristic curve of a universal motor, the ordinates give the speed, the abscissae the torque. Curve (*b*) is a characteristic curve of the same motor, when a resistance, e.g., 45 ohm is inserted into the circuit. If the motor is equipped with a centrifugal contact governor adjusted to 3,000 r.p.m. it will work on the curve (a) as long as the contacts are closed, and on curve (*b*) when they are open. The governor will close and open the contact with high frequency and will keep the speed of the motor constant at this value for any load within the two curves (*a*) and (*b*) for which the diagram is drawn. For a load exceeding this interval the speed will decrease according to curve (*a*), for lower loads it will increase according to curve (*b*). The characteristic of the motor with centrifugal contact speed governor is shown in the diagram by the heavier parts of the curves. The horizontal part of the characteristic may be extended by providing a higher resistance, but this is not recommended, for unnecessary wear of the contacts would result.

The curves (*a*) and (*b*) are shifted to right or to left by a change of the applied voltage and by a change of the frequency. Such changes influence the value of the loads at which the regulation of the speed starts or ends.

The design of a simple centrifugal contact governor is shown in Fig. 3. The slip rings are fixed on the back of the disc shown in the drawing. The contacts (*d*) on the springs (*e*) are closed by the centrifugal force. The movement of the inner spring is limited by the parts (*i*) and (*g*). The maximum movement of (*g*) can be adjusted by the axial adjusting screw (*h*). By this screw the speed of the motor can be adjusted when running. When the inner spring is held by (*f*) so that it cannot follow the outer spring, the contact is opened and further increase of the speed of the motor is stopped. The pin (*i*) limits the deflection of the outer spring when the speed increases suddenly at light load. The regulator is balanced by a small weight (*k*).

A similar governor may also be used for the adjustment of the field current of a shunt motor.

Another design of a centrifugal contact governor is shown in Fig. 4. The springs with the contacts are fixed radially on the disc. Two or more contacts in parallel may be used. This design is suitable for larger currents, or when a long life of the contacts is desired. The spring (*c*) is stiffer than the spring (*b*). The springs are stretched by the centrifugal force, spring (*b*) more than spring (*c*), and the contact will open at higher speed. The position of the springs (*c*) can be adjusted by the disc (*d*) which carries the fingers (*e*). These fingers determine the position of the inner springs (*c*) and in consequence the speed at which the contacts open. This adjustment can be made when the motor is running. This design has been found very suitable for universal motors driving kitchen appliances.

A great advantage of the motor with centrifugal contact governor is that it develops full starting torque whatever the adjustment of the regulator—a condition which does not exist in the case of a motor with a resistance in the main circuit. This is important for the drive of accounting machines, book-keeping machines and other similar purposes.

The governor described may be applied for speeds between 500 and 8,000 r.p.m. Oscillograms of the current show that the frequency of the opening and closing of the regulator contact has a value between 200 and 800 per sec. Appropriate speeds for the motors are between 3,500 and 4,500 r.p.m. For a supply which changes frequently from d.-c. to a.-c., it is preferable to use a speed between 5,000 and 7,000 r.p.m.

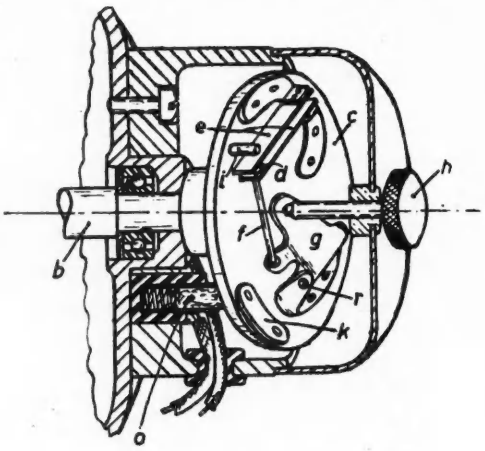


Fig. 3. Centrifugal contact governor.

a Brushes; *b* Axle of the motor; *c* Rotating disc; *d* Contacts of the governor; *e* Springs; *h* Adjusting screw; *i* Limiting pin; *k* Balance weight.

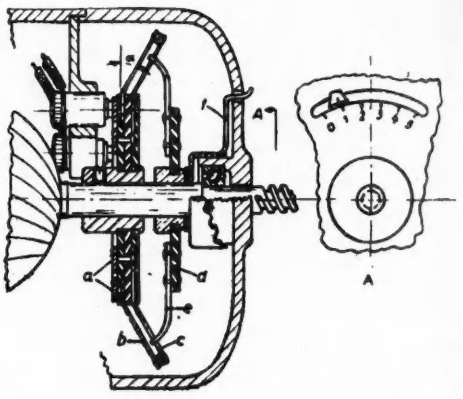


Fig. 4. Another design of a centrifugal contact governor.

a Slip rings; *b* Outer contact spring; *c* Inner contact spring; *d* Adjusting disc; *e* Fingers for the adjustment; *f* Lever for the adjustment of the speed.

THE NEW B.M.W. COMBINATION WITH WHEEL DRIVE

By ST. VON SZÉNÁSY. (From *ATZ- Automobiltechnische Zeitschrift*, Vol. 45, No. 14, 25th July, 1942, pp. 400-402).

IN collaboration with the German Military Authorities two new motor cycle combinations have been developed

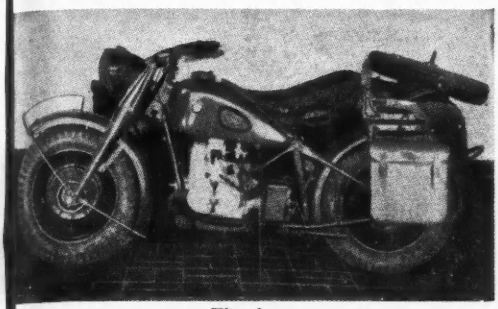


Fig. 1.

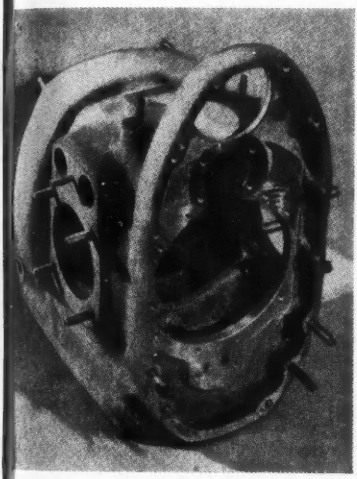


Fig. 2.

in which in addition to the rear wheel of the motor cycle the wheel of the side-car has also a positive drive. Details of the first one, the Zundapp KS 750, have been published recently. The present article describes the BMW R 75 of 750 cm³ (Fig. 1). It contains features typical to all BMW machines, and in addition, new ideas have been incorporated on solving the problems connected with the requirement for good hill-climbing qualities.

The engine is a twin with horizontally opposed cylinders. The crank case and gear-box (Fig. 2) made of light alloy, are integral cast. The light alloy cylinder heads form a semi-spherical combustion chamber. This is shown in Fig. 3, where also further details can be seen. The valve control consists of the cam-shaft, driven by the crank-shaft which operates the two valves via cam, push rod and rocker arms, the push rod being set at 45°.

To save weight, the valve tappets are hollow with lightening slots through the walls, these slots are "spiral" to avoid scoring the guide. The cast iron valve seats are shrunk into the detachable light-alloy heads.

The crank-shaft is built-up and supported by three bearings. The connecting rods have roller bearings, the cages of which are made of elektron.

The carburetter is of the two-float type. The exhaust pipes are bent forward to meet in a single pipe arranged in front of and across the engine, to which the silencer is attached.

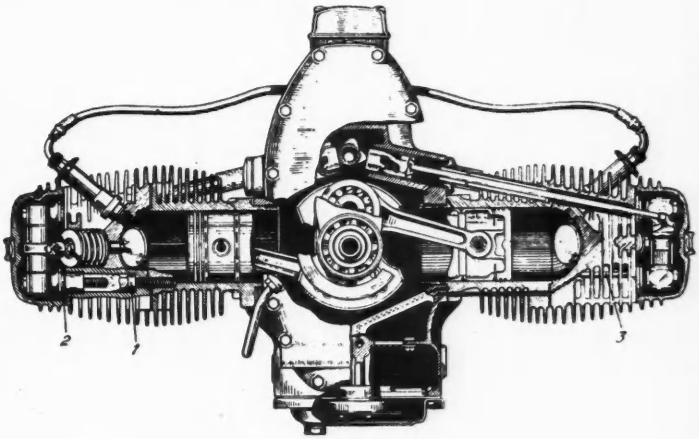


Fig. 3.

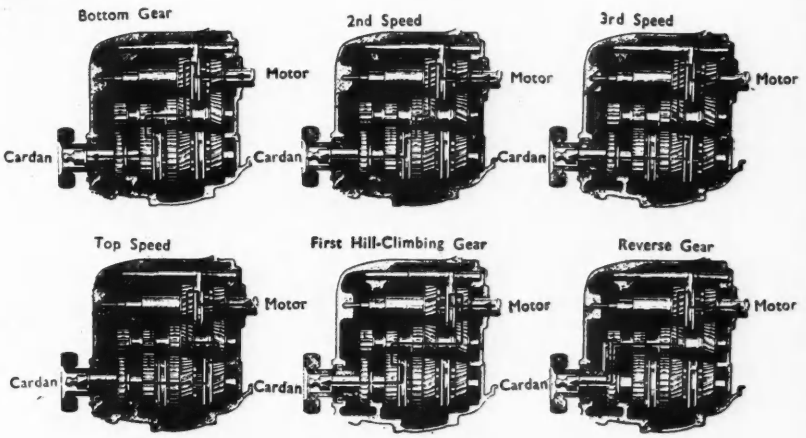
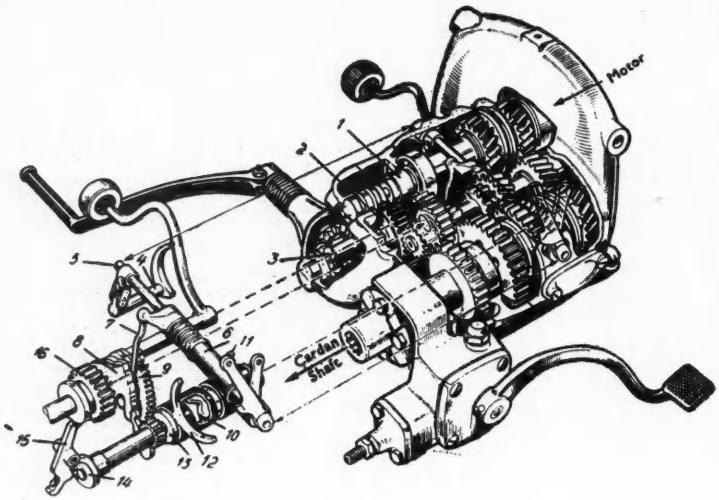


Fig. 4



1 = Clutch thrust-bearing
2 = Starting wheel
3 = Starting bevel gear
4 = Change fork for hill-climbing gear
5 = Change shaft for hill-climbing gear
6 = Gear lever (hand)
7 = Connector
8 = Gear locking device
9 = Toothed segment for gear change
10 = Curved groove
11 = Lever to 3rd and 4th gear
12 = Lever to 1st & 2nd gear
13 = Gear change barrel
14 = Actuating cam
15 = Lever for intermediate gear wheel
16 = Gear wheel for reverse speed

Fig. 5.

For the first time in motor cycle design, the magneto is provided with automatic advance and retard by means of a centrifugal governor. The magneto is a NORIS ZG 2a with fixed make-and-brake and automatic adjustment up to 35°. The Type DS 6/50 dynamo is specially designed by NORIS, and has an output of 50/70-Watt.

The most interesting part of the machine is the gear-box, which is cast integral with the crank case. The gear is a three-shaft gear employing spur gear wheels and helical gear wheels. The wheels of the four forward speeds are in constant mesh.

Gear changing for forward speeds is operated by a pedal; in addition, a hand-lever is provided. For gear changing from "road-gear" to "hill-climbing" gear there is a special hand lever. Fig. 5 illustrates the construction and working of the gearbox, for which the principle of gearing is given in

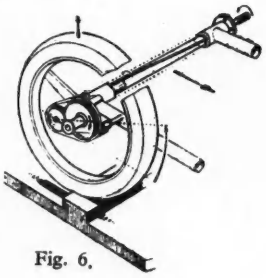


Fig. 6.

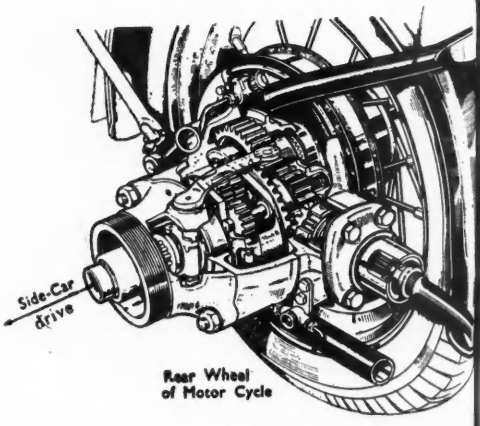


Fig. 8.

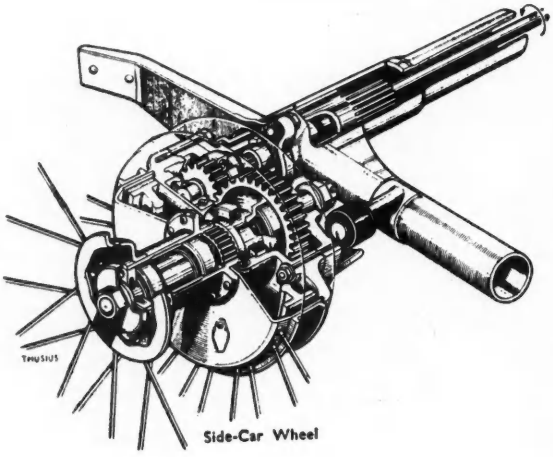


Fig. 7.

Fig. 4. The reverse gear is actuated by the hand lever only. A push knob and locking device prevents the accidental use of the reverse gear. As with all BMW types, the driving shaft of the R 75 is fitted with universal joints.

The differential gear employs spur gear wheels, and its peculiarity is that the rear wheel obtains a greater torque than the side-car wheel. This gear can be locked.

The torsion springing system of the side-car wheel is shown in Figs. 6, 7 and 8. Fig. 7 shows also the differential gear attached to the rear wheel.

The torsion suspension for the side-car wheel consists of a tubular member embracing the outer end of the driving shaft and rigidly attached to the outer reduction gear casing and, at the inner end, splined into the outer tube enclosing the shaft drive. The twisting of this allows for a rise and fall of the wheel which is

limited by a rubber lined stop attached to the side-car supporting member.

The figures show that due to the spur gear wheels in the swing-arm, the axis of the side-car wheel is considerably in front of the rear wheel axis. This contributes to the good road holding qualities of the unit.

The tubular parts of the frame are screwed together, the centre part of frame is of box-section (Fig. 9).

The braking system is very much the same as that used on cars. The front wheel brake is hand operated by means of a cable, the rear wheel and the side-car wheel are actuated by pedal and are hydraulic. The side-car can be disconnected without loss of fluid from the braking system, since a special valve is incorporated. The vehicle has wire spoked wheels, which—for the first time in motor cycle construction—have the spokes arranged in two planes, both perpendicular to the wheel axis.

The side-car frame is built-up from tubes which are welded together. Summing up the more important technical data are :

Bore and stroke.....78 mm.
Output 28 h.p. at 4000 r.p.m.
Maximum speed 95 km/hour.
Gear ratio with road-gear :
Bottom gear.....1 : 3.22
2nd speed.....1 : 1.83
3rd speed.....1 : 1.21
Top speed.....1 : 0.90
Reverse speed.....1 : 2.41

The hill-climbing gear has three speeds only, 1:4.46,1:2.54,1:.67.

Fuel consumption is 6.3 litres/100 km. Climbing ability, at least 40% for long climbs and full load, for normal road conditions increased up to 50%. Fuel tank contents, 24 litres, range, about 380 km.

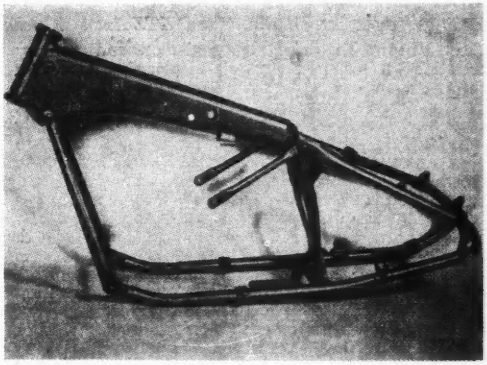


Fig. 9.

THE THOMA-DEMAG GEAR

(From *Schweizerische Bauzeitung*, Vol. 120, No. 14, October 3rd, 1942, p. 164).

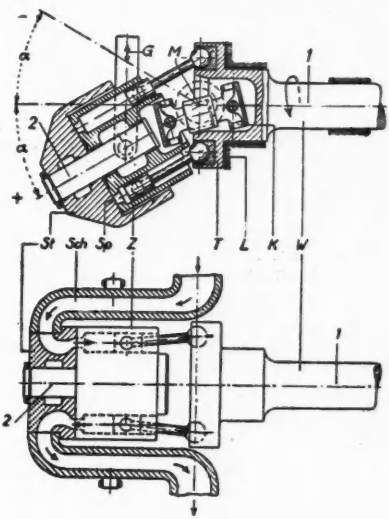
THIS hydraulic gear is described in the June, 1942, trade publication of the firm DEMAG. With ships driven by high-speed diesel engines, a hydraulic clutch between engine and the pinion of the toothed gear eliminates uneven torque and enables an elastic, shock-free and controllable power-transmission. The gear is a hydraulic-gear with a closed oil circuit, and its design is based on the idea of Prof. H. Thoma (Karlsruhe). It consists of a primary and a secondary part, both parts being identical design. The figure shows one part only.

The axes 1 and 2 are fixed in space ; 1 is the diesel engine shaft for the primary part, and it is the shaft of the pinion for the secondary part. In the primary part the plunger gear works as a pump which pumps the oil in the circuit through the hydraulic-gear of the secondary part which serves as an oil-motor driving the pinion.

The cylinder Z in which the plunger slide rotates about axis 2, due to the cardan-joint K, a rotation of shaft W about 1 forces the cylinder to rotate about 2. Hereby, the plungers move up and down, as their rods are ball-jointed to the flange of shaft W. For a speed n_1 of the diesel-engine shaft, and given dimensions and angle of swing α_1 of the pump, a certain volume of oil is pressed through the motor per second. The speed n_2 of the pinion shaft depends on the dimensions of the secondary part, its angle of swing α_2 and on the load. According to whether $\alpha_1 = 0$, or $\alpha_2 = 0$, the pump respectively the motor is out of action. If the dimension of pump and motor are equal, than for $\alpha_1 = \alpha_2$, also $n_2 = n_1$ when the engine is idling ; load, however, causes a certain slip. Under the simplifying assumption of constant oil pressure, by changing the angle α_2, the power can be kept constant ; by changing α_1, a constant torque can be obtained. Generally for all conditions a simultaneous primary- and secondary control will suffice.

A swing over on the primary side ($\alpha_1 < 0$) exchanges the pressure side with the suction side of the pump and thus reverses the oilstream and the direction of rotation of the pinion shaft. The change of the angle of swing is achieved by means of the control rod 6. As M is the axis about which the cylinder can swing, it is also the axis of the rigid pipe-line joining the control channel Sch in the control block St.

As power is being transmitted mainly via the connecting rods whereas the cardan joint is a mere kinematic member, in the bearing L at higher loads high axial pressures are encountered. These are counter-



balanced by means of the channels Sp. On a gear designed to transmit 1000 h.p. at 375 r.p.m., tests were carried out successfully with periodical increase up to 1500 h.p. and 100 atm. for shorter periods. Reversal tests were incorporated, and the maximum gear-efficiency measured was 84%. The Thoma-Demag gear answers the call for a powerful reversal—and control gear such as—apart from the use described above—are needed for electro-hydraulic drives, for cranes and in mining.

REMOTE TRANSMISSION AND RECORDING OF TORQUE, SPEED AND POWER

By DIPL.. ING. ENGEL, Berlin. (From *ATZ Automobiltechnische Zeitschrift*, Vol. 45, No. 7, 10th April, 1942, pp. 191-192)

DRIVING torque is being measured more and more by transmission torque-meters. The electrical side is a direct-current or alternating-current motor, the housing of which is supported on bearings and maintains its position by weights or spring balances. If correctly designed, the torque on the housing is almost equal to that of the shaft of the engine under test. Errors due to whirling of air are dependent on the engine speed, and can be fully corrected, so that the difference between torque of housing and shaft disappears. By measuring the torque and speed, the power is obtained.

With test benches for big engines the lay-out is often such that direct reading of the balance and of the speed indicator is not possible, and remote transmission becomes necessary. The electrical transmission of the torque is by a resistance-transmitter (direct or alternating current), actuating a suitable measuring instrument. The transmitter consists of a ring-shaped resistance with rotating brush collectors which are coupled to the axle of the balance. To achieve correct indication the frictional torque of the brushes should not exceed 0.5 gcm.

For the remote transmission of speed a transmitter consisting of a small direct current motor with a permanent magnet, transmitting a voltage proportional to the speed, is attached to the electrical torque-meter. The indicator is a moving-coil measuring instrument.

The AEG has developed a recording instrument for recording torque and speed simultaneously. This double recorder consists of a ratiometer and a moving-coil measuring instrument; a record is drawn on the same strip of paper for ease for comparing the instantaneous values.

Direct indication of power is made possible by the AEG transmitter. The total resistance of the resistance transmitter is connected to three fixed resistances to form a Wheatstone bridge across which the voltage of the speed transmitter is applied through moving contact brushes. The indicating instrument is connected across the other diagonal of the bridge (Fig. 1).

By a suitable selection of the resistances, the bridge is balanced when the brush is in the end-position "a"; this corresponds to zero power, when there is no torque. In any other position the bridge is out of balance. In the other end-position "b" of the brush, the instrument current rises with increasing voltage from zero to maximum. This corresponds to a rise in power at maximum torque with increasing speed. Thus it is clear that the instrument current is a measure of the power, as it is proportional to the product torque × speed, and the change between the limits a and b is continuous and linear. In this way the measurement of power is reduced to an indirect measurement of current.

1 = Resistance transmitter.
2 = Bridge resistances.
3 = Torque transmitter.
4 = Indicator.

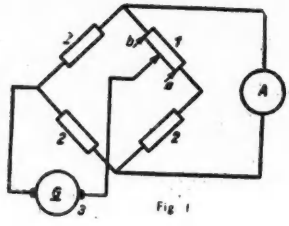


Fig. 1

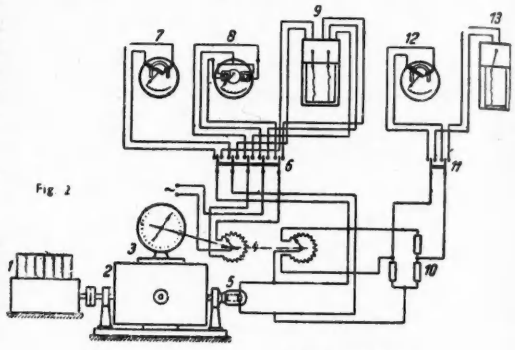


Fig. 2

1 = Engine under test
2 = Transmission torque meter
3 = Torque meter
4 = Double resistance transmitter
5 = Speed transmitter
6 = Switch
7 = Speed indicator
8 = Torque indicator
9 = Double recorder for torque and speed
10 = Bridge resistances
11 = Switch
12 = Power indicator
13 = Power recorder

Fig. 2 gives a survey of the possibilities of measurement and the principles of wiring. The two switches shown in the figure are necessary as the resistance transmitters are fitted with two sets only.

As regards accuracy, it is obvious that the errors of the several instruments are additive, and cannot, therefore, be neglected. The total error with normal test meters can be put to about ± 1.5%, and with normal recording instruments to about ± 2%.

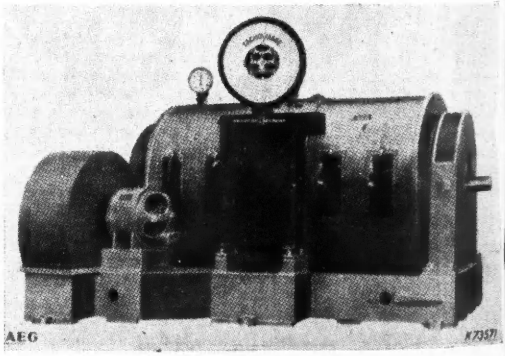


Fig. 3

TECHNICAL NEWS

Announcements in this section include News relating to British Firms, and on Equipment produced by British Manufacturers.

Available literature may be secured by addressing a request to the advertising department of "The Engineers' Digest," or by writing direct to the manufacturer and mentioning "The Engineers' Digest" as a source.

- NEW EQUIPMENT
- BOOKS AND CATALOGUES
- BUSINESS CHANGES
- PERSONAL
- NOTES

NEW EQUIPMENT

VALUE OF MICROCOPYING.

MICROCOPYING is, simply explained, the making of miniature negatives on 35 mm. film; these occupy a small space, are most conveniently stored and are easy to read. When the information is required the negative can be enlarged on to bromide paper in the usual manner well known to all photographers, but in quantity this is expensive. The best method, and one which answers all normal requirements, is to project the negative image in a viewer or reading machine to a convenient size to enable it to be read easily, but such machines are not readily obtainable now; a satisfactory expedient is to make use of a photographic enlarger to project the image. This is quite satisfactory in practice.

The negatives when made are in continuous lengths like ordinary cinema film. The lengths may be up to 5 feet if exposed in an amateur camera, or up to 100 to 200 feet if exposed in one of the specially made microcopying cameras which are essential if large quantities of work are to be undertaken.

In some libraries it is convenient to treat each issue of a periodical, or each annual volume, as though it were a book and file it as one unit, but microcopying offers the advantage that each article can be treated as a separate entity and be both indexed and filed in its appropriate place with other related information, filing for example being in accordance with the Decimal Classification. For this purpose the film is cut up into short lengths and filed in envelopes.

When taking micro-negatives it is advisable to decide first how the negatives will be filed and then to make an appropriate filing entry, with the essential data in large letters, on a fairly large card. The appropriate card is then photographed at the beginning and end of each article when it will be found that the large lettering is easily readable with the naked eye, a great advantage when working with a number of negatives which might otherwise become muddled. Also when photographing a number of articles in a journal it should be remembered that when one ends and another begins on a given page, this page should be photographed twice to enable the articles to be separated; of course, if the title cards suggested above are used this immediately becomes obvious.

The leading photographic manufacturers make very fine grained, contrasty emulsions capable of recording the minute detail involved when reducing printed matter twenty or more times. A particularly useful booklet is "The Technique of Micro-Copying," published by Ilford Limited, which recommends the Ilford Micro-Neg. panchromatic film and gives much useful data about exposure conditions and methods of processing the negatives.

With regard to cameras, libraries would be adequately served by a camera fixed in position and with the focus of the lens also fixed. There would then be a maximum size of document which could be photographed and everything smaller would appear correspondingly smaller on the negatives. If difficulty were experienced in fitting up such an apparatus, film manufacturers would be willing to give assistance. Similarly if the librarian is unable to develop his own negatives, these can be forwarded to the manufacturer who has a development service available.

As indicated previously, the only real obstacle to the development of micro-copying is the comparative shortage of suitable micro-readers. Just recently, however, Messrs. Wray Ltd., of Bromley, Kent, have made available a small reader suitable for short lengths of film. Another important development is the inauguration of the ASLIB Microfilm Service by the Association of Special Libraries in conjunction with the Science Library. This Service is rapidly making available on microfilm the scientific publications of enemy and occupied countries since 1939, so as to fill the gaps left by inability to obtain these publications.

MUREX DECK WELDER.

THE demand for increased welding speeds in ship construction has resulted in the development of new types of equipments and electrodes. The aim throughout has been to deposit more pounds of metal per operator per hour utilising if possible semi-skilled operators and achieve these results without any deterioration in the mechanical properties of the metal being deposited, or the joint being welded. Simplicity in operation was, therefore, very important, and with these points in mind Murex Welding Processes Limited developed the Murex "Deck Welder."

The electrical supply can be taken straight from standard welding transformers designed to comply with B.S.S. 1071. The "Deck Welder" takes the place of the usual electrode holder in the circuit. 500 to 600 amperes A.C. with an open circuit voltage of 90/100 are necessary and this supply can be obtained by using the normal 600 ampere regulator or by paralleling two 300 ampere regulators.

The triangular frame structure of the welder is approximately 30 from base to apex. This structure is supported at three points which are locating points determining the line along which the weld will be made. A small carriage carrying an electrode holder and electrode is allowed to fall freely down one member of the structure from a point adjacent to the apex. The electrode is in continuous contact with the plate being welded, but is so designed that the coating of the electrode melts at a speed which enables a flow of metal to pass from the core to the joint being welded. No attention is required during the actual welding operation, consequently it is possible for one operator to employ two or more equipments on adjacent seams.

The total weight of the equipment is under 30 lbs. and is therefore easily portable by one operator to any part of the ship.

A special type of electrode known as "Fastex 2" has been developed for use with this equipment.

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NEW CAPSTAN LATHE.

THE new redesigned C.V.A. precision capstan lathe would appear to be a machine with a wide range of usefulness. It has a speed range enabling practically all materials to be dealt with and its greatest scope is in the manufacture of what may be classed as small precision repetition parts. The two most interesting parts of the lathe are probably the headstock and the gearbox.

The spindle of the headstock is of nitralloy and is mounted on adjustable phosphor bronze bearings which are lubricated by wick feed oilers. A new type of quick action collet attachment with a capacity up to $\frac{5}{8}$ ins. has been incorporated in the spindle and another special feature is an arrangement whereby a new belt can be fitted without completely dismounting the headstock, it being a simple matter to remove the headstock cover and the endshield when the belt can then be threaded between the end of the spindle and the housing.

The gear box is of the internal expanding clutch type and gives instantaneous spindle speed changes or reversals. The speed range is such as to make the lathe suitable for all materials, including the screwing of high tensile steel.

The manufacturers of the C.V.A. precision capstan lathe are A. C. Wickman Ltd., of Coventry.

BENCH GRINDING AND LAPPING MACHINE.

THERE is a very great sphere of usefulness for bench machine tools, and the development of types of these has been accelerated in recent years. It is of interest, therefore, that A. C. Wickman Ltd., of Coventry, have recently marketed the Wickman-Neven Bench Grinding and Lapping machine which has been designed for the use of Neven impregnated diamond wheels.

A special feature of this machine is the swivel guard which is easily reversible, thus enabling one side of the wheel to be completely covered when not in use. It is worth mentioning, also, that the direction of rotation of the spindle can be reversed enabling right or left hand tools to be lapped with maximum convenience. There is a protractor scale and the table is adjusted by a micrometer screw from 0 - 5° negative and 0 - 15° positive.

The size of the table is 12 ins. by 8 ins., the overall dimensions of the machine 26½ ins. by 16½ ins. by 16½ ins. and the weight of the machine with the table is approximately 134 pounds.

PERSONAL

Mr. Richard Hazleton, General Secretary of the Institution of Production Engineers, has died recently.

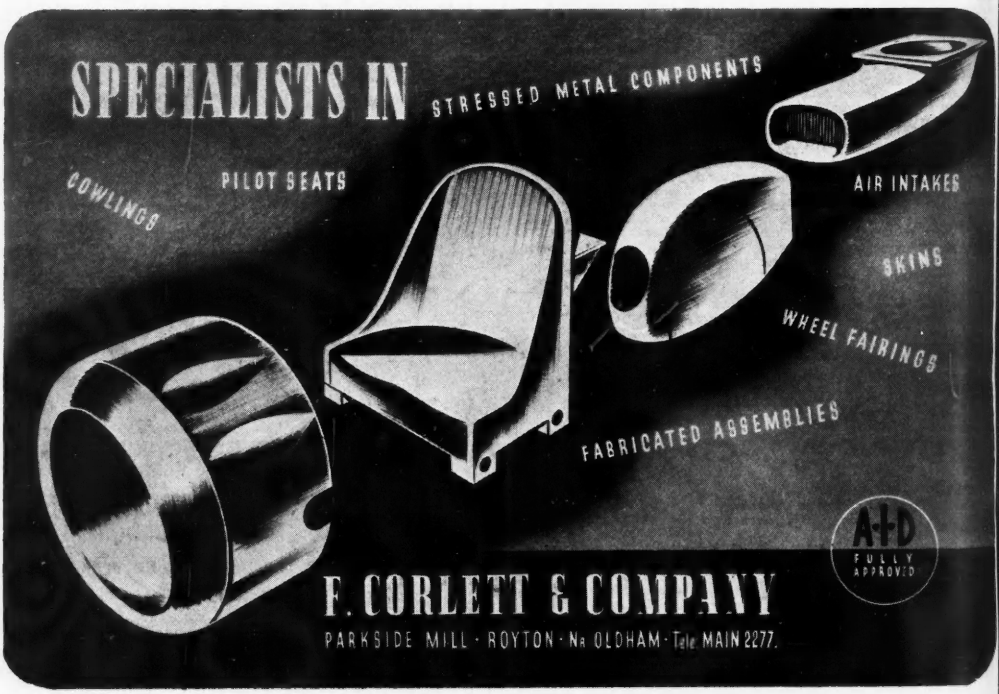
Mr. G. L. Kirkpatrick, M.I.E.E., Managing Director of Bruce, Peebles & Co., Ltd., of Edinburgh, has died recently.

Sir George Nelson, Chairman and Managing Director of the English Electric Co., Ltd., is to be nominated President of the Federation of British Industries.

Mr. Francis W. Rowe is to join the Board of Kryn & Lahy (1928) Ltd., of Letchworth, as Managing Director, on April 1st, 1943. Mr. Rowe, until recently was on the board of David Brown & Sons (Huddersfield), Ltd., and was General Manager of their Penistone Works. Mr. Rowe is well known to engineers and foundrymen, and has been the recipient of many honours for his work in the field of engineering and metallurgy. He has been with David Brown & Sons (Huddersfield), Ltd., for nearly 20 years, and has been associated with many of the developments for which that Company is famous.

Dr. F. S. Sinnatt, C.B., M.B.E., D.Sc., F.R.S., Director of Fuel Research, has died recently.

New Chief of Air Research.—Sir Stafford Cripps, Minister of Aircraft Production, has appointed Prof. Sir. B. Melvill Jones, Professor of Aeronautics at Cambridge University, Chairman of the Aeronautical Research Committee, with effect from April 1st, 1943.

Joint Aluminium Committee.—A combined Aluminium Committee to co-ordinate the activities of the United Kingdom, the United States and Canada regarding aluminium has been established in the U.S.A. Chairman of the Committee is Mr. Charles E. Wilson; the other members are Sir Richard Fairey and Mr. George C. Bateman.

The Modern Power Station.—The Royal Society of Arts, John Adam Street, London, W.C.2, has arranged on this subject a series of four lectures held by E. L. Luly, of Messrs. Babcock & Wilcox, Ltd., on The Boiler House; J. F. Roy Mitchell, of Mitchell Engineering, Ltd., on Coal and Ash Handling Plant; F. Shakeshaft, of the Central Electricity Board, on the Mechanical Equipment of the Turbine House; and C. W. Marshall, of the Central Electricity Board, on High Voltage Power Circuit Control.